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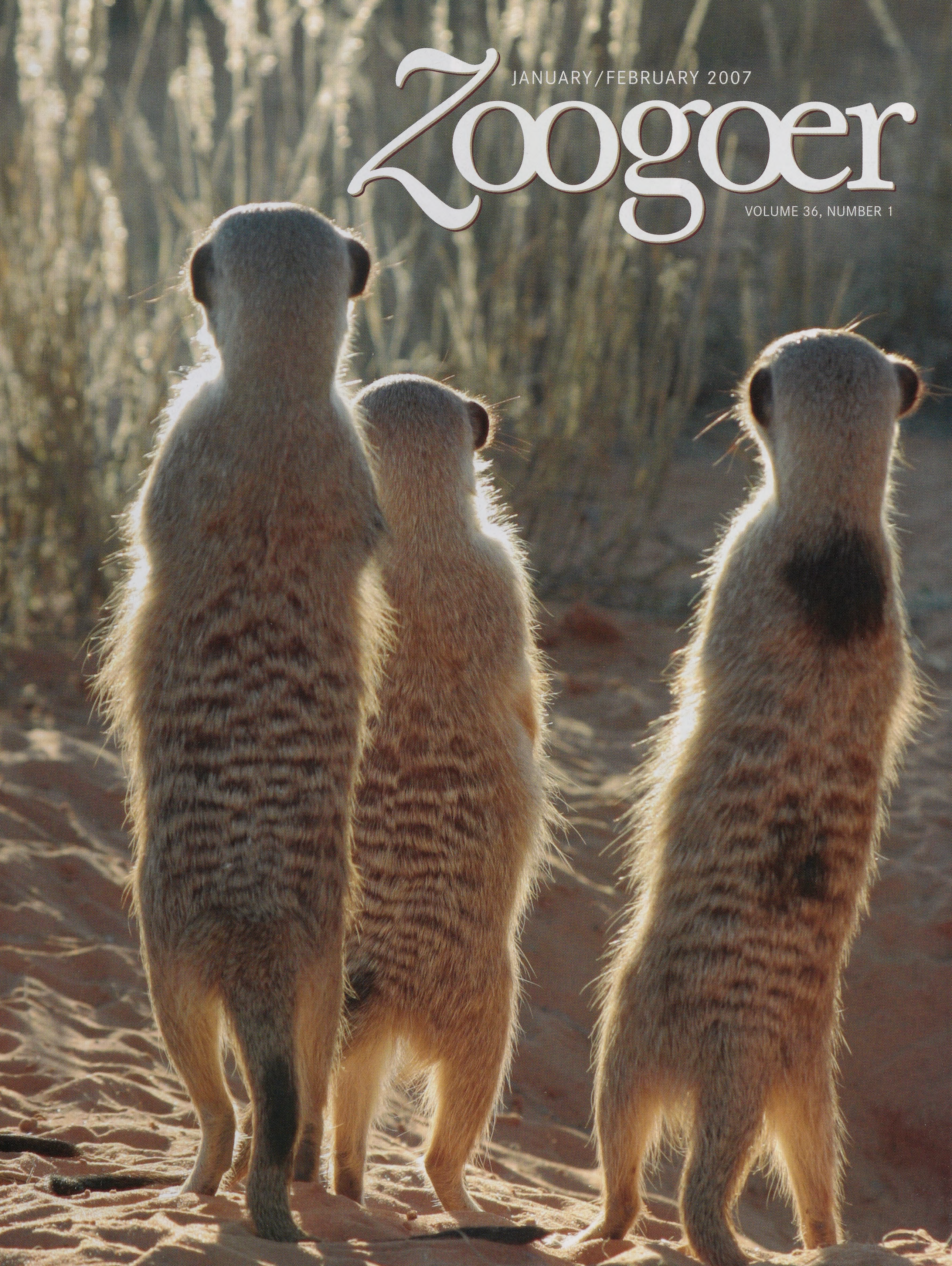

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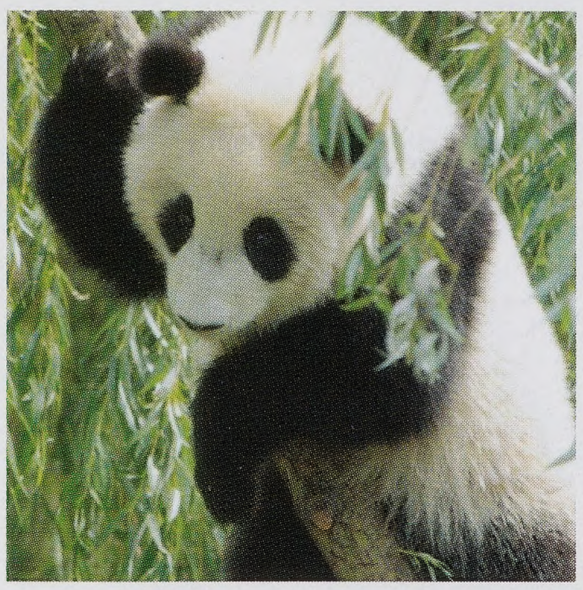

FONZ
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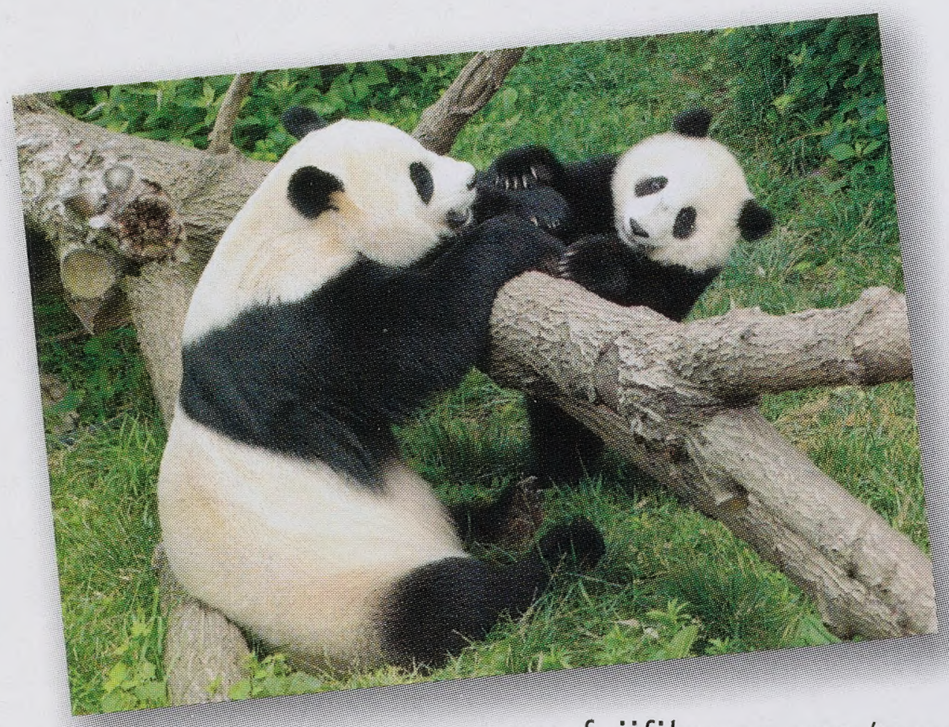
Fujifilm, the Smithsonian's National Zoo and Friends of the National Zoo are working together to help protect giant pandas and secure their future through education and research.

Visit and enjoy giant pandas Mei Xiang, Tian Tian and Tai Shan at the Fujifilm Giant Panda Habitat as well as six other Asian species along Asia Trail.



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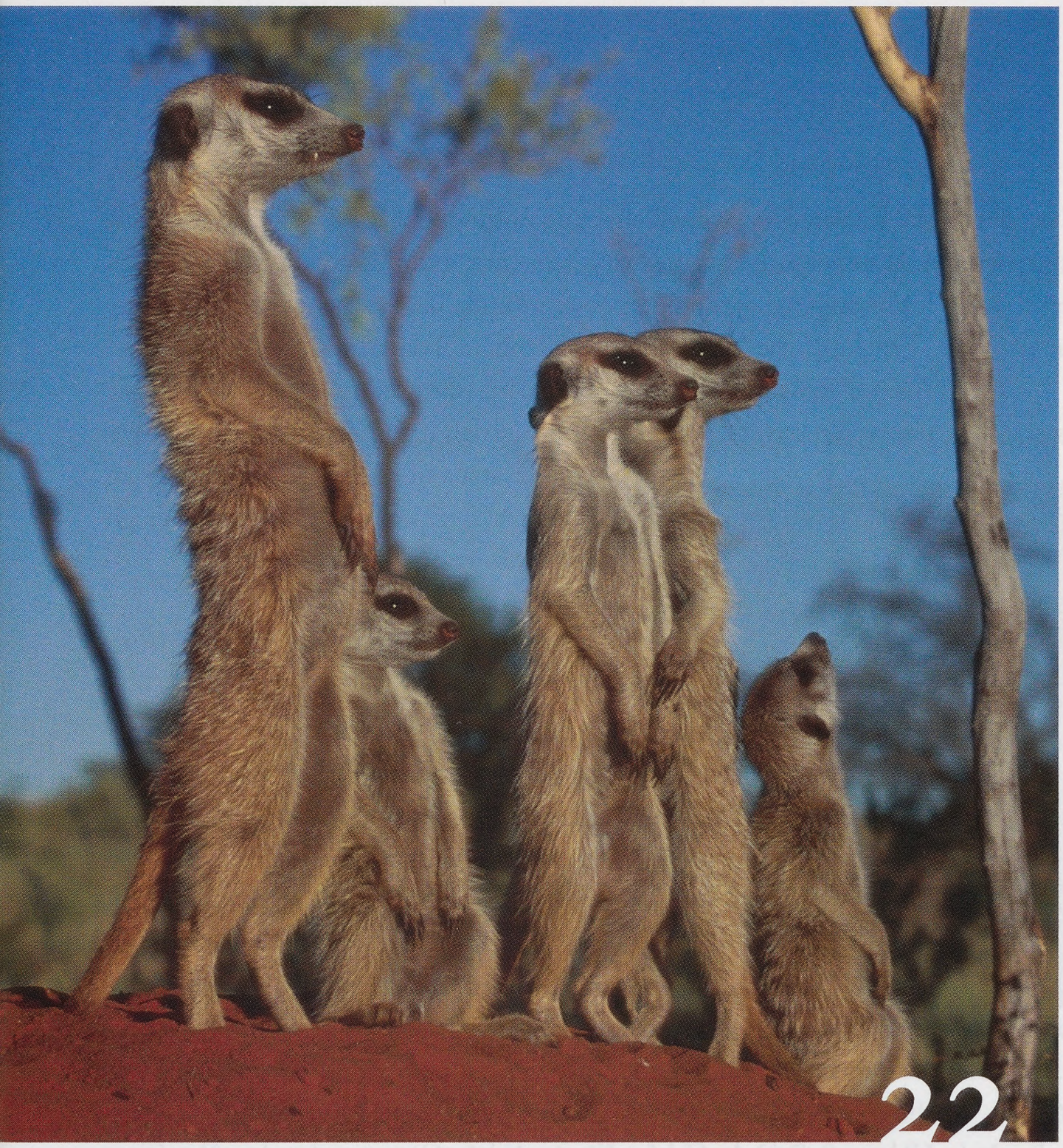

Bat: Kim Taylor/naturepl.com. Petrel: Francis Zino/Freira Conservation Project. Meerkats: Simon King/naturepl.com.

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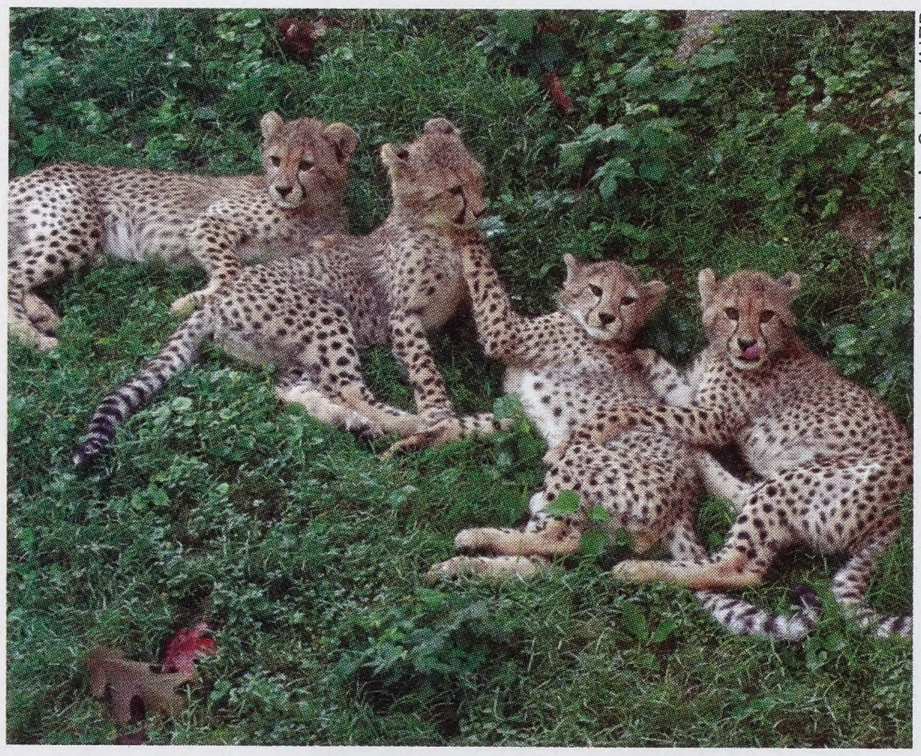
We're on Our Way!

Last January we charted an ambitious course—to make the National Zoo the world's finest zoo, and FONZ the world's best zoo-support organization, by 2016. The first year of this effort was a critical time for building momentum strong enough to carry us from our early planning stages all the way to our ultimate success.

By all accounts, 2006 exceeded our expectations as the start of great things to come. Some of the year's achievements became international news, such as the October opening of Asia Trail and the Fujifilm Giant Panda Habitat, a significant step forward in our ten-year revitalization program. Others, including Zoo education programs that reached more than 1.8 million individuals, did not make splashy headlines but are just as fundamental to the mission and future of our Zoo.

We are pleased to share with you and all the Friends of the National Zoo just a few of the highlights of a spectacular 2006.



Jessie Cohen/NZP

A cheetah science facility is being planned.

Increasing Membership, Visitation, and Support

More than 2.6 million people visited the Zoo in 2006, eclipsed only by attendance in 2001, when 2.8 million people visited and giant pandas Mei Xiang and Tian Tian made their debut.

For the first time ever, more than 40,000 households representing more than 100,000 individuals were members of FONZ.

FONZ reported unprecedented fundraising success in 2006. Proceeds from ZooFari, which raised $450,000, the Adopt a Species program, and other activities, along with the year's record-breaking concessions income, support a vast array of Zoo education, exhibition, science, conservation, and communications programs.

Renewing the Zoo

Animals new to the Zoo in 2006 included: a sloth bear cub born at the Zoo on January 9; a kiwi chick that hatched at the Bird House on February 13; three tiger cubs born at the Zoo on May 24; two wild-born sea lion pups abandoned or orphaned by their mothers that went on exhibit in Beaver Valley in May; and three young lions from South Africa that came to the Great Cats exhibit in November.

Asia Trail, a series of exhibits featuring seven Asian species, opened to the public in October, with the generous support of lead corporate sponsor Fujifilm, exclusive media sponsor Animal Planet, and additional sponsors and private donors.

Other new exhibits and improvements in 2006 included: new interpretive signs in the free-ranging golden lion tamarin exhibit and the Reptile Discovery Center; an outdoor enclosure for a pair of giant anteaters that went on exhibit in July; and a beautifully landscaped hummingbird garden next to the Panda Café.

In June, the Zoo launched Elephant Trails: A Campaign to Save Asian Elephants, a comprehensive breeding, education, and scientific research program. As part of this campaign, the Zoo will create an expanded, state-of-the-art facility for Asian elephants. Learn more about the campaign at **www.fonz.org/elephants.htm**.

Advancing Science Excellence

Two National Zoo scientists were formally recognized in 2006 for their dedication to conservation. In June, Katherine Ralls, a senior scientist in the Zoo's Department of Conservation Biology, received an Honorary Fellowship with the Zoological Society of London, based on her work in behavioral ecology, genetics, and conservation of mammals. And in August, Jonathan D. Ballou, head of the Zoo's Department of Conservation Biology, received the 2006 Ulysses S. Seal Award for Innovation in Conservation.

In August, a team of National Zoo scientists began a two-year expedition in McMurdo Sound, Antarctica, where they are studying Weddell seals. Follow their progress at **www.fonz.org/antarctic.htm**.

In October, the Zoo announced the creation of the Fujifilm Curatorial Residency in Animal Care, a competitively awarded, two-year post-doctoral residency that begins in the summer of 2007.

Plans were begun in 2006 to build a cheetah science facility at the Zoo's Conservation and Research Center (CRC) in Front Royal, Virginia, that will house up to 30 cheetahs. Through research at the facility, Zoo scientists will increase their knowledge of cheetah reproduction, behavior, nutrition, and veterinary medicine.

In a breakthrough study early in 2006, Zoo scientists produced the first coral larvae from frozen sperm, proving that cryopreservation of gametes is a viable conservation strategy for endangered coral. In August, they began developing a genetic bank of frozen samples.

Expanding the Public We Serve

Zoo and FONZ educators reached more than 1.8 million individuals through classes, curricula, interpretive outreach, and other programs.

People visited the Zoo/FONZ website, which features educational material on Zoo science and conservation, species, and ecosystems, about 35 million times and generated more than 120 million unique page views.

2006 At a Glance

- The award-winning Asia Trail opened in October to rave reviews and smiling faces.
- The Zoo was visited by more than 2.6 million people, and its website was visited about 35 million times.
- FONZ provided $7.5 million to support and improve the Zoo.
- More than 1,500 generous FONZ volunteers provided more than 90,000 hours of service to the Zoo.
- The Zoo committed $31 million to begin its next major renewal project, Elephant Trails, providing expanded elephant acreage and trails, conservation education and science, and enriched visitor experience.

The 2006 Autumn Conservation Festival set an attendance record when it gave more than 4,300 visitors a behind-the-scenes look at Zoo scientists' work at CRC.

Operating With Care

The Zoo reduced its consumption of electricity by 22 percent and natural gas by 21 percent, resulting in a 16 percent decrease in energy costs for the fiscal year.

Asia Trail was awarded the 2006 Presidential Citation for Sustainability in Design by the D.C. chapter of the American Institute of Architects for its ecofriendly elements, which include natural paving and a recycled bridge.

The Zoo became a nonsmoking facility in December to reduce the risk of fire and to ensure the safety of its animals and staff. A new fire protection plan was also devised in 2006, and more than $6 million was secured for safety initiatives.

In March, the Zoo began preparations to protect animals, staff, and visitors against a potential outbreak of the highly pathogenic H5N1 avian influenza.

Working together, Zoo and FONZ staff, FONZ members and donors, corporate sponsors, volunteers, Congress, and the Smithsonian are well on the way to realizing our goals for 2016. With your continued support, we are poised to overcome the challenges we will undoubtedly face in the year ahead.

Wishing You the Best in the New Year,

John Berry
Director, Smithsonian's National Zoological Park

Bob Lamb
Executive Director, Friends of the National Zoo

FONZ Friends of the National Zoo is a nonprofit organization dedicated to supporting the conservation, education, and research efforts of the Smithsonian's National Zoo. Formed in 1958, FONZ was one of the first conservation organizations in the nation's capital. Friends of the National Zoo is dedicated to supporting the National Zoo in a joint mission to study, celebrate, and protect the diversity of animals and their habitats.

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Smithsonian **National Zoological Park** is located at 3001 Connecticut Ave., N.W., Washington, D.C., 20008-2537. Weather permitting, the Zoo is open every day except December 25. Hours: From October 29, 2006, to March 10, 2007, grounds are open from 6 a.m. to 6 p.m.; buildings, 10 a.m. to 4:30 p.m. From March 11, 2007, to November 4, 2007, grounds are open from 6 a.m. to 8 p.m.; buildings, 10 a.m. to 6 p.m.

Membership in FONZ offers many benefits: programs, publications, discounts on shopping and events, free parking, and invitations to special programs and activities to make zoogoing more enjoyable and educational. To join, write FONZ Membership, National Zoological Park, 3001 Connecticut Ave., N.W., Washington, D.C., 20008-2537, call 202.633.3034, or go to www.fonz.org.

Membership categories and annual tax-deductible dues are:

Household	$55
Young Professional	$40
Individual	$40
Senior	$35
Contributing	$100
Sustaining	$150
Patron	$250
Sponsor	$500
Benefactor	$1000
Director's Circle	$2500
ZooGoer (for those outside a 200-mile radius of Washington, D.C.)	$30

($8 of membership dues goes to a ZooGoer subscription)

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An audio version of ZooGoer is available on our website, for members who cannot read standard print due to disability. For more information, please visit **www.fonz.org/zoogoer.htm.**

On the cover: On the cover: Meerkat (***Suricata suricatta***) sentinels keep a wary lookout for predators near their burrows in the Kalahari Desert. Photo by Miles Roberts.

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Mehgan Murphy/NZP

A sunbittern chick, which hatched on October 13, and its father on their nest at the Bird House's Indoor Flight Room. Both sunbittern parents care for their offspring.

Animal News

If you need a little sun to brighten your winter days, visit the pair of **sunbitterns** (*Eurypyga helias*) and their single offspring at the Smithsonian National Zoo's Bird House. Sunbitterns are native to Central and South America, where they inhabit wooded swamps and humid forests. At rest, their mottled brown, white, and black markings help them blend in with the colors of branches or soil. But when they spread their wings they display beautiful patterns of red, black, and gold feathers that resemble the rays of the sun. The offspring at the Bird House emerged from its egg on October 13, and was the first sunbittern to hatch at the National Zoo in 11 years.

Also at the Bird House, two species new to the Zoo, **guira cuckoos** (*Guira guira*) and a **spotted dikkop** (*Burhinus capensis*), went on exhibit in December. Guira cuckoos are native to the eastern half of South America, where they inhabit open, scrubby areas. They are highly social and live in communal roosts and nests; unlike some cuckoos, they are not parasitic, and raise their own young. Spotted dikkops are predominately terrestrial and are native to eastern and southern Africa, where they inhabit open savanna or sparsely wooded or bushy areas. By day, spotted dikkops tend to rest in the shade, and forage for insects, mollusks, crustaceans, and amphibians at night.

The Farm Inn

Female lion Nababiep.

Three **African lions** (*Panthera leo*) born at the Farm Inn in Pretoria, South Africa, arrived at the Zoo on October 30; at press time, they were scheduled to debut at the Great Cats exhibit in December. Male Luke is one year old, and females Shera and Nababiep are two. The lions were brought to the Zoo based on the recommendations of a Species Survival Plan, a consortium of North American zoos that, under the auspices of the Association of Zoos and Aquariums, manages genetic diversity in lions. The Zoo's other lion, 15-year-old female Lusaka, has been at the Great Cats exhibit for three years.

In preparation for the construction of Elephant Trails, the Zoo's expansive new habitat for **Asian elephants** (*Elephas maximus*), Randle, a **Rothschild's giraffe** (*Giraffa camelopardalis rothschildi*), was sent to Lowry Park Zoo in Tampa, Florida, in November.

Lectures

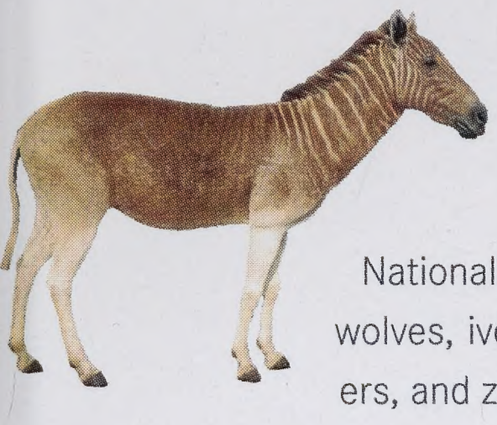
Lectures at the National Zoo now begin at 7 p.m. They are free and open to the public. For more information and to RSVP, visit **www.fonz.org/lectures.htm**.

Ancient DNA Solves Mysteries of Nature

January 11—7 p.m.

How do scientists determine whether extinct species are related to each other, and to living species? How do they identify which plants or animals have been used in tribal or ancient artifacts? The Smithsonian Genetics Program has been at the forefront of answering these kinds of questions, by developing and applying techniques for analyzing ancient DNA. Join Rob Fleischer, acting director of the Zoo's new Center for Conservation and Evolutionary Genetics, as he describes fascinating cases of DNA detective work at the National Zoo involving Indian wolves, ivory-billed woodpeckers, and zebra-like quaggas.

Reinhold Rau



The Science of Love and Attachment

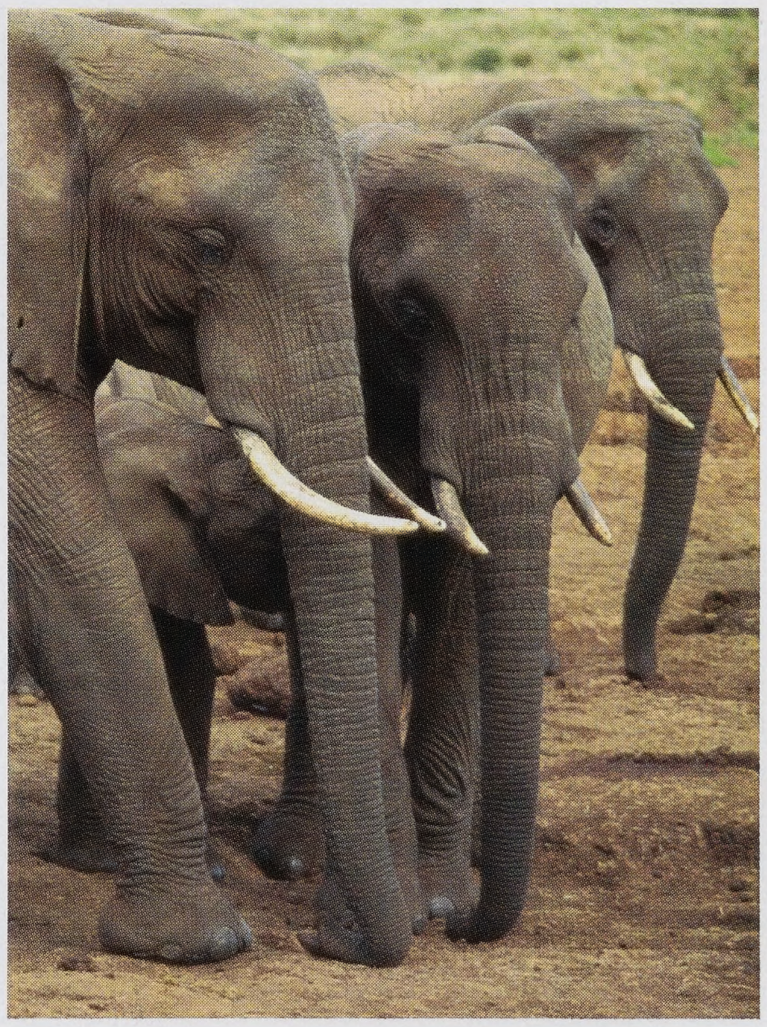
February 8—7 p.m.

In cooperation with the Foundation for the Advancement of Behavioral and Brain Sciences, the National Zoo is hosting a Valentine's Day lecture on "The Science of Love and Attachment." Look for details at **www.fonz.org/lectures.htm**.

Kinship and the Social Lives of African Elephants

February 22—7 p.m.

Female African elephants have rich and complicated social lives, forming close and enduring bonds and social networks that span hundreds of animals—on par with chimpanzees, dolphins, and humans. Beth Archie, a FONZ-supported postdoctoral Fellow in the Smithsonian Genetics Program, will talk about her work studying kinship and the social relationships of the African elephants living in Kenya's Amboseli National Park. These elephants have been studied by Cynthia Moss and the Amboseli Elephant Research Project since 1972, and are one of the best-known populations of elephants in the world.



Volunteer Corner

Jessie Cohen/NZP

Volunteer Leslie Reed interacts with visitors.

As 2007 begins, it's refreshing to look back at the successes of the past year, and 2006 was one of the Zoo's best years ever. Such success could not have been possible without the support of more than 1,500 Friends of the National Zoo volunteers, who donated more than 90,000 hours of their time to the Zoo, its animals, and its visitors in 2006. These dedicated people contributed to diverse programs throughout the Zoo: Their ranks included exhibit interpreters, keeper aides, behavior watchers, and horticulture, special events, commissary, and Zoo on Wheels volunteers. They came from all walks of life, and spanned a wide range of ages, from 13-year-olds to senior citizens. And their enthusiasm for the Zoo inspired staff and visitors alike.

If you are looking for a rewarding volunteer experience, visit **www.fonz.org/volunteer.htm** to find out which positions are currently open at the Zoo. In addition to learning more about animals and meeting new people, volunteers receive: free parking, a 20 percent discount in Zoo Stores at the Zoo and in local malls, a 30 percent discount at the Mane Restaurant and at food shops that have a cash register, free stroller rental, use of the Zoo library and FONZ volunteer lounge, a discount when joining FONZ, invitations to the annual volunteer party and field trips, volunteer travel opportunities, supplemental accident insurance while volunteering for FONZ, and one year's free membership in the Volunteer Association for the National Zoo.

Get the latest scoop on Zoo scientists' work at **www.fonz.org/science.htm**.

Mist forms around Pico do Areeiro, a Madeiran mountain that hosts a breeding population of rare Zino's petrels.

Jef Maion/Nomads' Land

Zino's Petrel

LOST AND FOUND

BY MALCOLM SMITH

It's approaching midnight and we're standing on a knife-edge mountain ridge. It's cold, dark as pitch, and windy. Eerie clouds swirl around us, making it impossible to see more than a couple of yards. We huddle on the dangerously narrow path, looking for shelter among a few boulders as squalls of powdered soil sting our faces.

This is my first visit to Madeira, a 450-square-mile Portuguese island that lies 400 miles off the west coast of Morocco, and ornithologist João Nunes is guiding me on my nocturnal expedition. We can barely make out the gloomy shape of the pock-marked cliffs behind us, and I am thankful that their precipitous slopes and deep, gouged valleys are left to our imagination. Aside from the wind, all has been silent since we walked onto this summit-ridge path on Pico do Areeiro an hour ago.

Francis Zino/Freira Conservation Project

Zino's petrels are graceful and agile in flight, but ungainly on land, where they nest and raise their young. Their awkwardness on the ground makes them vulnerable to introduced predators such as rats and feral cats.

Then, we hear a ghostly wail from somewhere in the dark sky around this mountain peak. And another, this one from a different direction. The shepherds who once grazed their goats on these hillsides say they are the cries of colleagues who have fallen off Madeira's ancient, volcanic mountains to their deaths. The sound is surreal, as if someone is trying to frighten us.

"That's it. That's their call," whispers Nunes. "The adults are flying in to locate their breeding burrows." The mysterious sounds do not belong to spirits, but to Zino's petrels (*Pterodroma madeira*), Europe's rarest breeding seabirds. There might be 80 breeding pairs of these gray-and-white birds on this Atlantic island, and they breed nowhere else in the world.

Every night, whether the skies are clear or veiled by dense clouds, each pair of petrels flies in from the sea, gains thousands of feet in altitude, and lands near its burrow. Ungainly on the ground, the birds shuffle the last few feet to their burrow's entrance to find and feed their solitary nestling.

The story of the Zino's petrel's discovery, presumed extinction, and rediscovery, coupled with its mysterious lifestyle, is extraordinary. But it's more than a fascinating tale. The threats this petrel faces, and the efforts to conserve and enhance its small population, mirror those of other island-breeding seabirds worldwide.

Life on the Edge

Zino's petrels are delicate birds with 32-inch wingspans and 13-inch-long bodies built for gliding over the ocean for long periods of time. It's hard to believe that such small seabirds fly up over steep valleys and navigate their way, in darkness, to nest among sheer rock pinnacles.

Pairs select a nesting site in late March at the beginning of the breeding season and begin constructing four-foot-long burrows in the cliffsides. "The birds dig them themselves, where there's friable soil, into very steep slopes," says Frank Zino, a doctor and ornithologist who is the son of the species' namesake. "You can always tell when you have young, prebreeding birds, because their nails are sharp enough to scratch you," he says. "On breeding birds, the nails are always blunt from digging."

Between mid-May and June, the female Zino's petrel lays a single white egg at the end of the burrow on a fairly rudimentary nest composed of pieces of grass. Each parent incubates the eggs for several days without eating, then trades places with the other parent.

The chick hatches at the end of July or early August. Tucked well inside a burrow set among rocky ledges, yellow-flowering broom, and desiccated grasses, it spends the first few months of its life totally isolated from the sea.

By early to mid-October, the growing chick feeds only every two or three nights. Then one night, it leaves its burrow under cover of darkness. On Madeira, all of the known nesting burrows face roughly northeast, the direction of the predominant winds. Presumably, that gives an increased chance of lift—and survival—to young Zino's petrels making their maiden flight to the sea.

Discovering a New Species

The Zino's petrel might have been known to science earlier, but for a case of mistaken identity. In 1903, a few of the birds were brought to Father Ernesto Schmitz, a priest and naturalist who lived on Madeira. He misidentified them as Fea's petrels (*Pterodroma feae*), which have similar plumage to Zino's petrels, but are bigger and heavier birds with larger bills. Fea's petrels breed in small numbers on Bugio, an island 15 miles southeast of Madeira, but not on Madeira itself.

The Zino's petrel might have been known to science earlier, but for a case of mistaken identity.

Father Schmitz left Madeira five years later, and memories of a petrel nesting high in Madeira's mountains faded. No one reported seeing or hearing the birds, and they were presumed extinct.

But in 1940, a young petrel that may have been disoriented by the lights of Madeira's capital, Funchal, was found dead on the grounds of the governor's palace. Frank Zino's father, Alec, an amateur ornithologist and owner of a small property business on Madeira, was familiar with Fea's petrels and he knew this bird was different. When he inspected another of the mysterious petrels that was found in Funchal in 1952, he was convinced he was looking at a new species, possibly the one Schmitz had examined 50 years before. "He was also sure that they weren't Fea's petrels because these fledged youngsters were found in October," says Frank. On Bugio, Fea's petrels don't fledge until December or later.

Alec Zino wasn't the first person to suggest that Father Schmitz had made a mistake. In a study published in the *Bulletin of the British Ornithologists' Club* in 1934, Australian ornithologist and petrel expert Gregory Mathews compared preserved Fea's petrel skins with those of the birds taken to Schmitz earlier that century. Mathews suggested that the two were sufficiently different to be separate subspecies.

Inspired by his examinations of the dead birds and Mathews' study, Alec visited Madeira's high mountains numerous times in the mid-1960s to listen for any calls that might be petrels. But he heard nothing. Perhaps, he thought, the birds had died out. Then, another possibility crossed his mind: If the birds breeding on Madeira were so physically similar to Fea's petrels that a man of Schmitz's experience could confuse them, then both birds' calls might be similar as well. So he recorded the calls of Fea's petrels on Bugio as they came in after dark to find their nesting burrows, and played the recordings for shepherds who grazed their sheep and goats on Madeira's mountains.

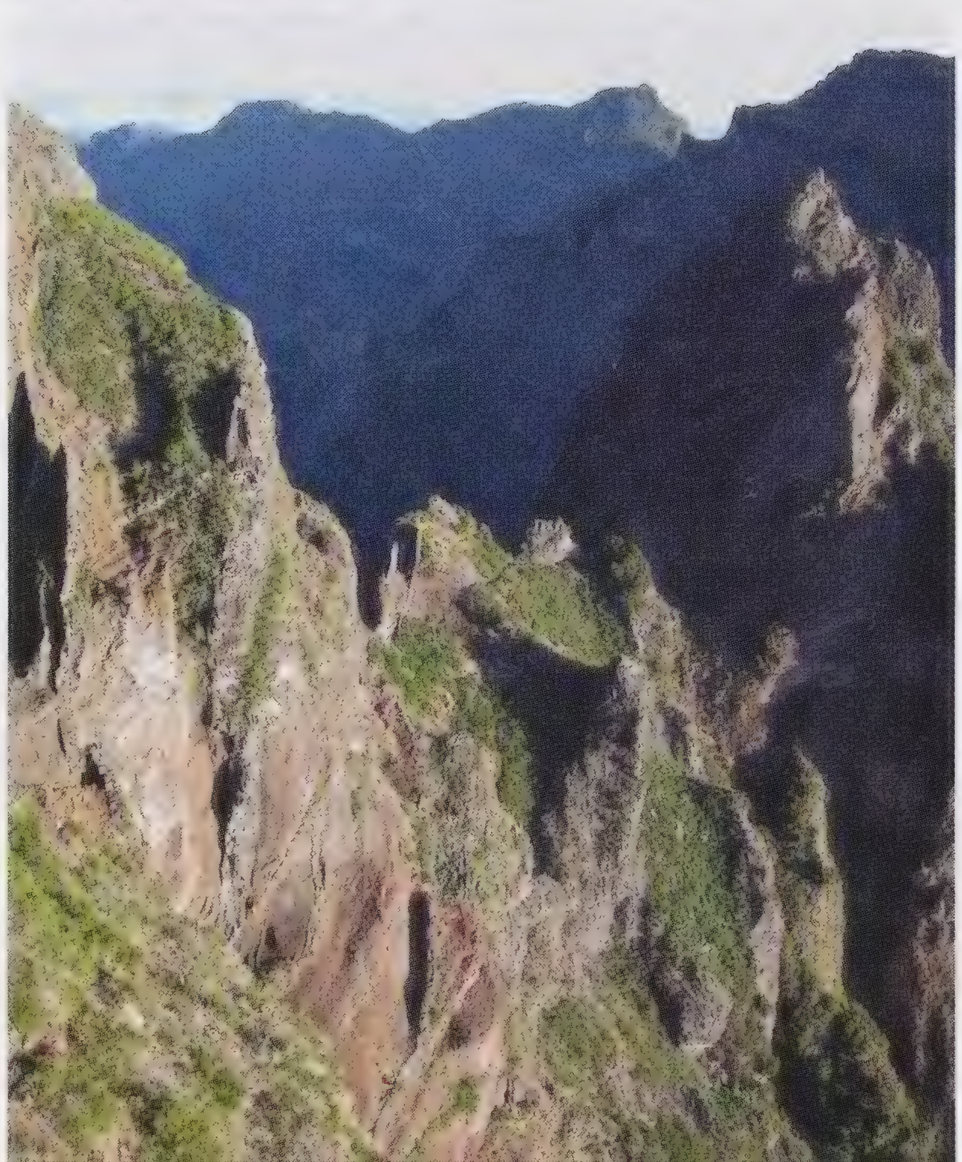
A shepherd named Lucas recognized the calls and said he knew where they could be heard. In April 1969, Lucas took Alec to the ridges where the petrels were breeding and they heard the ghostly, nocturnal wailing, confirming that the birds still existed. By mid-June that year, they found burrows with eggs.

Alec and Frank studied the birds, and in 1986 published a paper in *Boletin do Museu Municipal do Funchal* proclaiming that Madeira's petrels belonged to a species separate from Fea's petrels. The distinction was accepted by the scientific community.

Scientific names were created for the birds, but their common names were a different matter. In Portuguese, the petrels of Madeira were known as the *freira*, while Fea's petrels were called *gon-gon*. "But then we needed English names," recalls Frank. Fea's petrel was agreed upon for the Bugio birds. Alec and Frank proposed the name "Madeira petrel" for the other species, but it was too similar to the name of the Madeiran, or band-rumped, storm petrel (*Oceanodroma castro*), a very different-looking seabird. "So Bill Bourne [a leading British ornithologist and seabird expert] kindly suggested the name Zino's petrel in honor of my father. And the name stuck," says Frank.

Alec Zino died in 2004. He is generally referred to as the man who *re*discovered Zino's petrel, and the original discovery is attributed to Schmitz despite his misidentification of the bird.

Zino's petrels nest on this mountain ledge.



Francis Zino/Freira Conservation Project

An Enigmatic Bird

How many Zino's petrels are there? It's difficult to count them; their habitat is inaccessible, and the adults come to land only after dark.

In the first systematic monitoring of Zino's petrel burrows, in 1986, only one nesting area with six

occupied nests was found. Since then, the number of occupied burrows found in the original surveyed area has increased, and other nesting areas have been found. Today, there are six known nesting areas occupied by an estimated 60 to 80 breeding pairs.

According to Frank, who counts and studies the birds, new nesting sites may yet be discovered. With other ornithologists and conservationists, he has been putting identification bands, or rings, on all the young petrels found in burrows for several years and banding adult birds caught in mist nets at night. "But we are still catching some young adults that aren't sexually mature and are not ringed," he says. "These must be birds reared in burrows we haven't yet found. So there could be other breeding areas and perhaps we have more than 80 pairs."

If Zino's petrels are something of an enigma during the breeding season, where they spend the bulk of the year at sea is totally unknown. "Some American birders have told me that they've seen them off the east coast of the U.S. in winter," says Nunes. "But I think it's impossible to tell Fea's and Zino's apart when they are in flight over the sea, so I'm not convinced. They could be anywhere out in the Atlantic, maybe farther."

While the Zino's petrel's wingspan and body are a bit shorter than the Fea's petrel's, and its beak is a bit slimmer, these differences are hardly noticeable in flight. The crown and forehead of the Zino's petrel is a little paler than the Fea's, but try assessing that from a boat heaving in choppy seas while the bird skims low, twisting and turning with every motion of the waves.

Francis Zino/Freira Conservation Project

Frank Zino works with a Zino's petrel on Pico do Areeiro.

Decline and Recovery

Madeira wasn't always as it is today. The island was discovered in 1419 by the Portuguese explorer João Gonçalves Zarco, who spied it from his landing site on Porto Santo, an island about 30 miles to the northeast of Madeira. Zarco, whose statue graces a square in Funchal, named it Ilha da Madeira (Island of Wood) because of its dense cover of shrub-rich laurel forest.

When Madeira was uninhabited, its seabirds, including the Madeiran storm petrel and the Cory's shearwater (*Calonectris diomedea*), probably nested in burrows on forested slopes. Today, they still breed on slopes above the sea, although no trees grow there. The island's few hundred Manx shearwaters (*Puffinus puffinus*)—seabirds similar in size to Zino's petrel—continue to breed on forested slopes farther inland. Maybe some or all of the Zino's petrels excavated their burrows on forested slopes, too, and were more commonplace than they are today.

Fossilized bones matching today's Zino's petrels have been found on several parts of Madeira and on Porto Santo. Some were found in caves at lower elevations, suggesting that mountaintop breeding might be a relatively recent development. "Why they now breed exclusively so high up we don't know," says Frank. "Perhaps they moved up to get away from human disturbance, or from yellow-legged gulls [*Larus cachinnans*], which predate on young shearwaters and petrels breeding on low ground, or even perhaps from shepherd dogs."

Designed for life at sea, petrels and shearwaters are marathon fliers, wheeling and soaring between the waves on the lookout for small squid, surface crustaceans, and fish. They are also good swimmers. But on land, they are the archetypal "ducks out of water"; an ungainly, slow shuffle is all they can manage. They are so vulnerable to nocturnal land predators when they walk on the ground that they land as close to their nest entrances as possible.

For centuries after Madeira's discovery, seabirds and their eggs—including, presumably, Zino's petrels—have been eaten by introduced species. Black rats (*Rattus rattus*) escaped ships and soon became established in the countryside, where ground-nesting

Francis Zino/Freira Conservation Project

Zino's petrel.

seabirds and their eggs were an obvious source of summertime food. Cats, imported by the early settlers and popularly kept as pets on Madeira, frequently became feral and also preyed on seabirds. In the high mountains, too many sheep and goats have trampled the burrows of the Zino's petrel and eroded the steep slopes where they nest. In recent decades, egg collectors—attracted by the bird's rarity—have also taken their toll.

> They are so vulnerable to nocturnal land predators when they walk on the ground that they land as close to their nest entrances as possible.

Predation and habitat destruction steadily reduced the population. "All through the 1960s, '70s, and '80s, the breeding success of the known nesting sites was terribly low," comments Frank. In 1986, when systematic monitoring of the few breeding ledges that were known at the time began, none of the young birds survived the summer, and rats were strongly suspected as the killers. In 1991, feral cats killed ten adults in one breeding area. "Luckily, these petrels, like most other seabirds, are very long-lived. [Some petrels live up to 50 years.] Otherwise, I believe that the level of predation would have driven them to extinction."

In 1986, the Freira Conservation Project—a joint initiative among the Funchal Museum of Natural History, the Natural Park of Madeira, and the local community—was created to attract funding for regular monitoring of the birds and for predator control programs. Since the project's inception, poison baits have been put out to kill rats and feral cats have been trapped. These controls remain in place, as rats from lower ground replace those poisoned at higher elevations, and domestic cats are released into the hills by owners who no longer want to care for them.

Hugh Harrop/hughharrop.com

In flight, this Fea's petrel is nearly indistinguishable from a Zino's petrel.

Predator control is allowing Zino's petrel to prosper. Breeding success has increased, and few youngsters are now lost to rats and cats. Similar success was achieved with other rare island-breeding petrels, including the Bermuda petrel (*Pterodroma cahow*) and the Hawaiian petrel (*P. sandwichensis*). Both of these rare seabirds had nearly succumbed to introduced predators including rats, cats, dogs, and mongooses.

According to Isabel Fagundes, director of the Portuguese bird protection organization Sociedade Portuguesa para o Estudo das Aves, almost all of the seabird species that breed on Madeira and other offshore islands are increasing. "All the rats have been poisoned by the Madeira Natural Park Authority on the Desertas Islands and in the Selvagem Islands," which are 165 miles south of Madeira, she says. "These are very important places for a range of breeding seabirds. Their numbers are now increasing." Completely eradicating rats on a large, mountainous island like Madeira is impossible, and docking ships are likely to reintroduce them time and again. So, baiting and trapping around the Zino's petrel's breeding sites continues.

About 750 acres of the mountaintop area in which Zino's petrel breeds have been purchased by Madeira's Regional Government to ensure the species' protection. And Madeira's central mountains and laurel forests comprise a large portion of the 65 percent of the island set aside for conservation by the Madeira Natural Park Authority and protected by European Union conservation laws.

Shepherds are now banned from grazing goats and sheep on the highest land and a large area has been fenced, with grids on access roads, to keep them out. "The shepherds were compensated," says Fagundes. Frank and his colleagues from the Madeira Natural Park Authority who monitor the petrels have noticed a massive recovery in the mountain vegetation now that no livestock graze these topmost slopes. Erosion has declined, also.

Frank thinks that these factors could encourage the petrels to increase their numbers and extend their breeding to several mountain areas they do not currently inhabit. While it's impossible to know whether these new areas suit the Zino's petrel's precise breeding needs, conservationists are thinking about making them more attractive for nesting by installing artificial breeding tunnels, something that has been done successfully for some of the world's other rare petrels.

What's it like, I asked Frank Zino, to have a bird named after your family? "It's pretty exciting," he replied. "I feel a great sense of responsibility, but it's a fantastic honor, too." There's no doubt that Alec and Frank Zino's work has helped give the petrel much better prospects than it has had for a few hundred years. Z

—Malcolm Smith is chief scientist and senior director of the Countryside Council for Wales, in the United Kingdom.

Kim Taylor/naturepl.com

In an artist's composite, a brown long-eared bat (*Plecotus auritus*) hunts for insects attracted to an outdoor lamp. Bat species that forage near streetlights may be displacing those that don't.

night, INTERRUPTED

BY MARY-RUSSELL ROBERSON

Humans thrive in light. We move about during the day and sleep at night, third-shift workers and newborns notwithstanding. Sunshine helps us see, produce vitamin D, and regulate our sleeping patterns and moods. In the immortal words of John Denver, sunshine on our shoulders makes us happy.

When the sun goes down, we retreat into buildings flooded with artificial light. To ease nighttime travel and keep shadows at bay, we light our streets and yards as well. A few hours later, we turn off the bedside lights to sleep the rest of the night away.

From our diurnal point of view, nighttime is no time, a time for non-doing. We forget that for many of the world's creatures, nighttime is when the action happens. Fireflies signal to each other at dusk. Owls wake up to hunt. Frogs begin their chorus. Bats leave their roosts. Felines go on the prowl. Animals that are active at night have evolved diverse strategies for finding food and mates, avoiding predators, and communicating with each other under cover of darkness.

So what happens to these animals when the cover of darkness begins to fray?

Dietmar Nill/naturepl.com

The effects of artificial lighting on the nocturnal behaviors of animals, such as this west European hedgehog (*Erinaceus europaeus*), are not fully understood. Some species' foraging and breeding habits are severely hampered by a lack of natural darkness.

Night Light

In the absence of artificial light, illumination at night varies from inky darkness to a soft glow from the moon and stars. Moon phases are usually the most significant variables in nighttime illumination. Light from the sun bounces off the surface of the moon and shines back toward Earth; the percentage of the moon's face that appears lit up varies during the month as the Earth, moon, and sun change position relative to each other. Nights are darkest during a new moon, when the moon is between the Earth and the sun, and brightest during a full moon, when the Earth is between the sun and the moon.

Weather conditions and topography also affect nighttime illumination. Heavy cloud cover blocks light from the moon and stars. Snow on the ground reflects it, increasing illumination; patchy clouds can do the same. A mountaintop above tree line is brighter than a valley whose steep sides block light.

This natural ebb and flow of illumination is washed out by artificial nighttime lighting in many developed parts of the world. Almost two-thirds of the United States is at least ten percent brighter at night than it would be without artificial lighting. Most Americans can no longer see the Milky Way from where they live.

Light pollution can be divided into three categories—direct glare, sky glow, and intermittent variations. Direct glare is light shining directly on an object from a particular source, such as an unshielded street light or a backyard floodlight. Sky glow occurs when light shines skyward from the Earth, reflects off particles of dust and water vapor in the atmosphere, and bounces back to Earth. Low clouds increase sky glow by providing more reflective surfaces in the form of water vapor. When the night sky is lit up in the direction of a city that's too far away to see, that's sky glow. Glitzy Las Vegas produces sky glow that extends for more than 100 miles. Intermittent variations are brief flashes of light, such as those caused by the headlights from a passing car.

Most light pollution is caused by electric lights, so light pollution is primarily a problem in or near urban areas in developed nations. However, there are other sources as well—flares from offshore oil wells light up parts of Nigeria, North Africa, and Siberia. Lights from commercial fishing ships illuminate the night in the Sea of Japan. Wildfires overpower moonlight wherever they burn large enough.

All this nighttime light creates a problem for astronomers, who must build their telescopes in increasingly remote locations where light pollution does not obscure the stars. It also creates problems for animals.

While scientists have known for a long time that artificial lights disturb migrating birds and sea turtles, they have only recently started looking at the ecological effects of light pollution on other animals. Their data show that light pollution affects species in ways we are only beginning to understand.

Wayfinding

As early as 1884, scientists documented the tendency of migrating birds to circle lighthouses in huge numbers at night. Today lighthouses still attract birds, but communication towers and lit-up skyscrapers pose a bigger threat because there are so many of them.

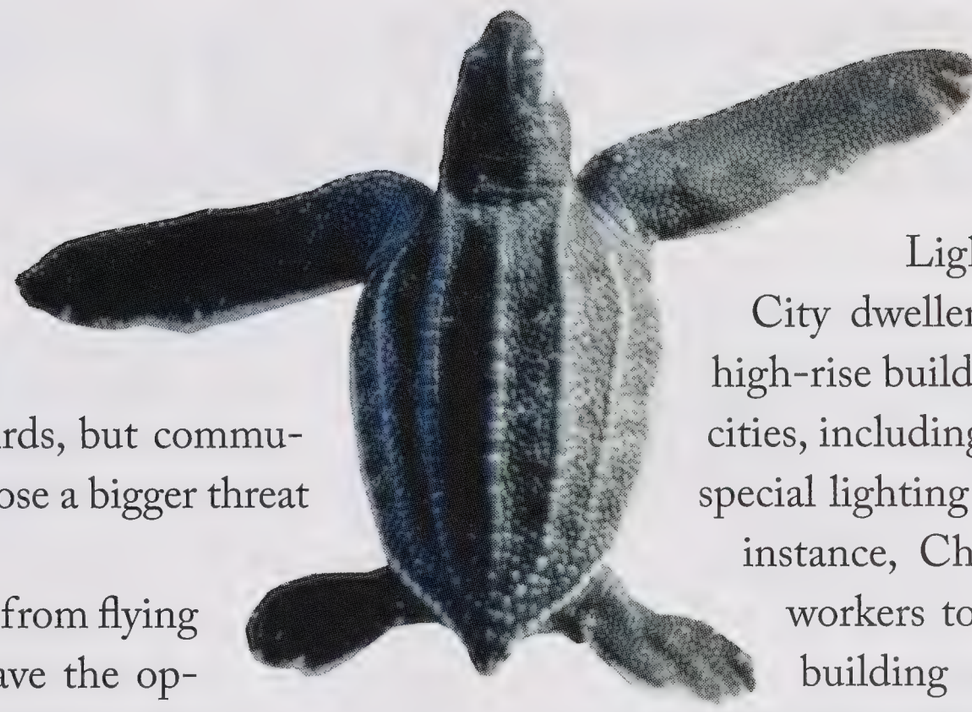
Towers are lighted to prevent aircraft from flying into them. Unfortunately, the lights have the opposite effect on some birds. Attracted to the lights, these birds sometimes circle the towers for hours and often have fatal collisions with other birds, the tower, or guy lines. Those birds that emerge from circling towers unscathed have wasted precious energy reserves needed for migration.

Charles Kemper, a retired physician, monitored a 1,000-foot-tall TV tower in Eau Claire, Wisconsin, every dawn during spring and fall migration seasons from 1957 until the late 1990s (he had a helper who filled in when he was unavailable). "I remember one night I was standing under the tower and birds were falling like raindrops," he says. "The engineer at the station came out and I talked him into turning the lights off for just a little while, and during this interval they quit. I didn't hear the collisions or [birds] hitting the ground."

One memorable September morning, he collected 11,000 birds at the base of the tower, all of which had died the night before. Kemper no longer monitors the tower, in part because he stopped finding significant numbers of dead birds there. He doesn't know why, but speculates that the increased number of communication towers in the area plays a part. Perhaps the bird collisions are spread out over the 30 or 40 towers that now stand in and around Eau Claire, not just concentrated at the one TV tower. It's also possible there are fewer migrating birds passing through the area.

Scientists aren't sure exactly why birds are attracted to lights, but have several theories. To fly in a straight path, birds may keep a constant angle between their flight trajectory and light rays from the moon; because the moon is far away, it does not appear to change position as the bird flies. But the same strategy used with a nearby artificial light would result in a trajectory that spirals in around the light source. Or it may be that artificial light somehow interferes with the inner magnetic compass that some scientists believe birds use for navigation during migration.

Sidney Gauthreaux, Jr., and Carroll Belser of the Clemson University Radar Ornithology Laboratory in Clemson, South Carolina, have observed lighted towers in the field and have found that birds are more attracted to red lights than to white, more attracted to constant lights than to strobes, and less likely to become "snared" by lights if they have a significant tailwind.



Leatherback sea turtle hatchling.

Frans Lanting/franslanting.com

Lighted skyscrapers also pose a problem. City dwellers often find dead birds at the base of high-rise buildings on spring and fall mornings. Several cities, including New York, Toronto, and Chicago, have special lighting guidelines during migratory season. For instance, Chicago's program encourages downtown workers to turn off their office lights at night and building owners to turn off exterior decorative lights after 11 p.m.

Sea turtles, which have been studied extensively along Florida's east coast, are also disoriented by artificial lights. Loggerheads (*Caretta caretta*) routinely lay their eggs there; leatherbacks (*Dermochelys coriacea*) and green turtles (*Chelonia mydas*) do so less commonly. Beachside development has left precious few dark beaches on the east coast of Florida, and female turtles are much more likely to lay their eggs in the sand on these dark beaches. If baby turtles hatch from their nests when the sand is hot, as it usually is in the daytime, they remain still in their nests; they wait until the sand cools, primarily at dusk or at night, to tunnel out and crawl toward the water.

When the hatchlings reach the surface of the sand, instinct directs them to crawl away from tall dark silhouettes and toward a low, uniform, dimly lit horizon. On an undeveloped beach, this instinct sends them into the surf: Sand dunes appear as tall, dark silhouettes and the ocean looks like a low uniform horizon that is dimly illuminated by the reflection of moonlight or starlight. On a developed beach, however, sky glow or house and street lights often lure baby turtles away from the ocean and toward death by predation, exhaustion, or cars. Scientists estimate that hundreds of thousands of hatchlings die this way in Florida every year.

On a developed beach, sky glow or house and street lights often lure baby turtles away from the ocean and toward death by predation, exhaustion, or cars.

Studies have shown that, as with birds, wavelength affects behavior of both mothers and hatchlings. In 1992, Blair Witherington of the Florida Marine Research Institute published the results of a field study of loggerheads in Florida and green turtles in Costa Rica that demonstrated that mercury vapor street lights (bright white) erected on the beach virtually eliminated nesting by females, while low-pressure sodium lights (yellow) had no effect on nesting rates as compared to a dark beach.

In laboratory studies carried out by Kristen Nelson and Susan Tuxbury at Florida Atlantic University in Boca Raton, hatchlings crawled toward lights designed to simulate standard street lights; some lights were clearly more attractive to the turtles than others. A higher percentage of hatchlings were attracted to mercury vapor lights than to high-pressure sodium lights (orange), and a higher percentage were attracted to high-pressure sodium than to those same lights equipped with "turtle-friendly" filters that decreased

MOONLIGHT NO DELIGHT FOR OCELOTS

We get it on most every night
when that moon gets big and bright
it's a supernatural delight
everybody's dancin' in the moonlight.
—Sherman Kelly,
"Dancin' in the Moonlight"

I see the bad moon arising.
I see trouble on the way.
—J.C. Fogerty,
"Bad Moon Rising"

James Carmichael/Bruce Coleman Inc.

To most of us, the idea of dancing in the light of a full moon is a romantic delight. For ocelots, a full moon is more like "the bad moon arising."

That was the tentative conclusion of a study by Louise Emmons, research associate at the Smithsonian's Museum of Natural History, and her colleagues, published in 1989 in the book ***Advances in Neotropical Ecology***, in a paper entitled "Ocelot Behavior in Moonlight." These biologists were studying ocelots (***Leopardus paradalis***) in Peruvian tropical rainforest. Ocelots are primarily nocturnal hunters but may be active day or night; as many cats do, they walk along trails and visit beaches while hunting their rodent prey. On trails and beaches, ocelots can walk more quietly and easily and see prey from farther away than if they were plowing through vegetation. But they do not use trails or visit beaches during the day, even when they are active, sticking to the cover of vegetation.

Emmons also found that ocelots generally avoid trails and beaches on nights with full moons, even though they are active just as many hours and walk just as far as they do on darker nights. It appears that the predators keep off brightly moonlit trails and stick to traveling under the darker cover of vegetation to look for a meal. In turn, their primary prey, nocturnal spiny rats (***Proechimys*** spp.), follow a similar pattern: They are more often seen on trails on dark nights than on bright nights, although they are equally active under both conditions.

Other evidence suggests, however, that ocelots are no more, and probably less, successful hunters when confined to vegetation, which likely hampers their ability to see prey, sneak up on it undetected, and pounce on it amid the undergrowth. Spiny mice and other small rodents, in contrast, probably avoid moonlit trails to decrease their risk of predation by birds of prey, which may be better able to see small animals when the night is bright. This forces the ocelots into the bush to find something to eat. It is also possible that avoiding trails and beaches during the day and full moons reduces the chances of ocelots themselves becoming the prey of jaguars (***Panthera onca***), pumas (***Puma concolor***), or harpy eagles (***Harpia harpyja***).

Other things being equal, a few days a month of eating a few less spiny mice is probably not a huge hardship for ocelots. But what if artificial night light forces them to stay under the cover of vegetation all the time? Or worse, what if there is no vegetation at all?

A small, endangered population of ocelots is clinging to survival in south Texas, in two refuges near or bordering the Rio Grande, which forms the international boundary between the U.S. and Mexico. These refuges do not form a large contiguous protected area; rather, protected tracts are linked by unprotected corridors that often lack vegetation. This probably makes it difficult for ocelots to move between the protected tracts. Making matters worse, to combat illegal immigration across the Rio Grande, the U.S. Immigration and Naturalization Service's Border Patrol burns and mows vegetation along the border and has installed miles of lights that brightly illuminate the border at night.

This concerns Melissa Grigione, a professor in the University of South Florida's Department of Environmental Science and Policy and cofounder of the Border Cats Working Group, which also focuses on the conservation of jaguars and jaguarundis (***Puma yagouaroundi***), which too are barely hanging on along the U.S.–Mexico border.

In a 2004 paper published in the journal ***Urban Ecosystems*** called "Effects of Artificial Night Lighting on Endangered Ocelots and Nocturnal Prey Along the United States-Mexico Border," Grigione and her colleague Robert Myrkalo reviewed existing studies, including Emmons', to assess what might happen to the Texas ocelots. They suggest that loss of vegetation in which ocelots can find cover while hunting or traveling between protected areas, and nocturnal artificial illumination that may alter the activity or abundance of rodents and reduce ocelot foraging success, may be serious threats to the recovery of these ocelots. Further, both night light and little cover may prevent them from moving across the Rio Grande to join populations in Mexico, and vice versa.

While experiments to test these ideas have not yet been conducted, Grigione says the prudent thing would be to eliminate artificial lighting or increase vegetation so ocelots and their prey have sufficient cover to shield them from artificial lights. Thus far, however, neither action is being taken.

—Susan Lumpkin

the amount of illumination by eliminating all but the amber wavelengths.

A field study at a beach near Boca Raton, Florida, examined the effectiveness of eliminating overhead street lights altogether and replacing them with light-emitting diodes embedded in the roadway. Lesley Bertolotti of the Broward County Department of Planning and Environmental Protection and Michael Salmon of Florida Atlantic University showed that the embedded light-emitting diodes were much less disruptive to hatchlings than conventional street lights equipped with the "turtle-friendly" amber filters. The embedded lights proved to be sufficient for the wayfinding needs of drivers, cyclists, and pedestrians, without interfering with the wayfinding needs of the baby turtles.

Eating and Being Eaten

Adding artificial light to habitats at night can disrupt nocturnal animals' strategies for eating and avoiding being eaten. An intriguing study led Robert Fisher, a research biologist with the United States Geological Survey, seems to have uncovered an example of this. Fisher has spent years surveying wildlife reserves in southern California. These pockets of wilderness are large enough to support a wide variety of biodiversity, but close enough to urban areas to be awash with sky glow. "In the coastal area where you've got low ceiling clouds at night, it's so bright there's no escaping it," Fisher says. The reserves are mostly coastal shrub and desert, so there is no significant tree cover to block sky glow from reaching the ground.

After extensive surveying, much of it done in collaboration with Ted Case, a retired professor at the University of California at San Diego, Fisher found that some nocturnal species that were previously documented in these reserves are now missing. For example, the glossy snake (*Arizona elegans*) and the western long-nose snake (*Rhinocheilus lecontei*) are gone. Their primary prey, which includes the nocturnal San Diego banded gecko (*Coleonyx variegatus abbotti*) and the Pacific pocket mouse (*Perognathus longimembris pacificus*), are also gone. "Some of these things are really inconspicuous and they are not things you'd expect to be declining based on the size of preserves and intactness of the habitat," Fisher says. "Why is this tiny mouse missing when all these bigger species of mammals, like bobcat and mountain lion, are still here?"

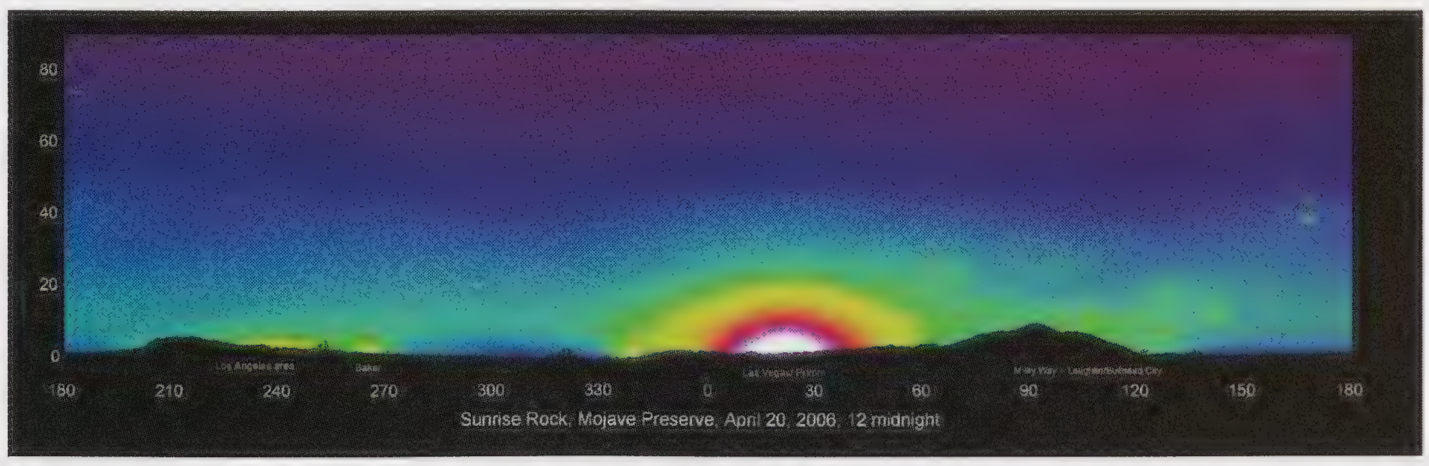
The mouse, gecko, and snakes still live in some darker parts of coastal southern California, such as the U.S. Marine Corps base Camp Pendleton and El Monte Canyon, which are both within 40 miles of San Diego. Fisher studied long-nose snakes' behavior in the field and discovered that they are most active on dark nights and least active around the full moon, when visibility is better for predators such as owls and cats.

Gopher snakes, which are ecologically similar to glossy and long-nose snakes except that they are active during the day, are flourishing in the southern California reserves.

Fisher has concluded that light pollution is the most likely culprit in the demise of the glossy and western long-nose snakes. "There are a whole bunch of questions, but the pattern seems pretty clear: Certain species that might be tracking the lunar cycle are gone," Fisher says. "We know that as soon as you get away from the brighter areas those species still exist." Fisher speculates that nocturnal snakes living in light-polluted areas don't come out to forage often enough, fall victim to predators more frequently, or suffer when their nocturnal prey dies out. "Brightness is going to affect a [nocturnal] species' ability to find prey or evade predators," he says.

On the opposite coast, Sharon Wise and Bryant Buchanan at Utica College in upstate New York are studying how sky glow affects the foraging behavior of nocturnal red-backed salamanders (*Plethodon cinereus*). Red-backed salamanders have no lungs; they absorb oxygen through their skins, which must stay moist. During the day, they seek shelter under leaf litter in the forest, and on wet nights, they come out to forage.

Wise and Buchanan set up 12 transects, each of which was 16 meters long and two meters wide. Six of the transects were each illuminated by one strand of small, white, electric holiday lights about one meter off the ground that simulated sky glow. "Our lights were very comparable to something between a full moon and twilight in a forest," Buchanan says.



Dan Duriscoe/NPS Night Sky Team

This composite photo was taken at the Mojave National Preserve in California and enhanced with false color to show distant sources of artificial light. The Los Angeles area, which is about 185 miles to the southwest, is represented by the small yellow glow toward the left of the horizon, while the Las Vegas area, about 65 miles to the northeast, is represented by the large, multicolored semicircle near the horizon's center.

The scientists surveyed all transects for foraging red-backed salamanders. Between one and two hours after dark, they found significantly fewer in the illuminated transects. Later in the night, they found no difference between transects that were illuminated and those that weren't, in terms of the number of salamanders out foraging. Because of difficulties with weather and logistics, they collected data only one night. Wise says, "In the next year or two we will try to set up some of these transects again so we can run [the study] over multiple nights and over a complete summer."

In the meantime, Wise and Buchanan have been working in

Red-backed salamander.

Sharon Wise

the laboratory to untangle the relative importance of the different cues—temperature, rainfall, and light—that salamanders use to decide when to emerge from the leaf litter to forage.

"Light is obviously important," Wise says. "If you go out on a rainy day and look for red-backed salamanders, they're not out. If you go out on a rainy night, you'll see them being active. What we're trying to determine is the level of light that is important." If it turns out that sky glow does inhibit salamanders from coming out to forage, that could have negative implications for their survival. On the other hand, Wise points out, there are confounding factors. "Lights may give them less time to forage," she says, "but if the lights are attracting insects, there may be more for them to forage on."

Other species also take advantage of insects' attraction to light to snare an easy meal. For example, frogs, geckos, and bats congregate at streetlights to forage on clouds of insects that swarm the lights. But Buchanan says, "Even if it superficially looks good for the frog, it might not be. It really does potentially expose the animals to a great increase in traffic-induced mortalities."

Insects are attracted to mercury-vapor lights and high-pressure sodium lights. Both of these emit some ultraviolet wavelengths, whereas low-pressure sodium lights give off a nearly monochromatic yellow light that contains no ultraviolet wavelengths and does not attract insects. Scientists surveying for bats with ultrasound detectors find increased concentrations of bats near mercury-vapor and high-pressure sodium lights.

In some cases, there is evidence that bats that take advantage of insect-attracting streetlights may be displacing species that don't. In several valleys in Switzerland, lesser horseshoe bats (*Rhinolophus hipposideros*) disappeared after streetlights were installed. At the same time and in the same areas, populations of common pipistrelle bats (*Pipistrellus pipistrellus*) increased. The two species are similar in size and diet, but pipistrelles eat at streetlights and lesser horseshoe bats don't.

Mating and Life Cycle

Most anurans (frogs and toads) are nocturnal. In the spring and summer, as daylight fades, male anurans begin their chorus to attract mates. Buchanan, who studies both anurans and salamanders, found that his outdoor enclosure of frogs was silent on nights when the nearby football stadium was lit up. The frogs would not chorus unless he shielded the enclosure with black plastic. Frogs that don't sing don't attract mates.

The football stadium observation is anecdotal, but Buchanan and Wise, along with Utica College undergraduates Heidi Savage and Kaylyn Bingel, performed controlled laboratory experiments showing that increased light levels at night have measurable effects on tadpole development in African clawed frogs (*Xenopus laevis*). They reared clawed frog tadpoles under controlled-temperature and varied nighttime-light conditions. "It appears that even light levels as dim as twilight will delay metamorphosis," Buchanan says. "That's potentially a real hardcore message for tadpoles." African clawed frogs live in water permanently, so perhaps there's no disadvantage to spending more time as a tadpole. However, if this finding holds true for tadpoles that develop in ephemeral ponds, nighttime light could pose a significant liability. "A lot of species have to metamorphose before the pond dries up," he says. "Delaying metamorphosis can prevent you from getting out of the pond."

Buchanan says more research is needed to untangle the ways in which light affects hormone levels, foraging, predator-prey relationships, and other factors. He adds, "One thing that is certain is that increasing light in a natural habitat will affect the ecology of the organism one way or the other. It's almost unfathomable that it wouldn't."

Las Vegas lights blaze at night.

Communication

Fireflies are masters of the art of nighttime communication. There are thousands of species of fireflies worldwide, most of which are nocturnal and use self-generated bioluminescence to communicate. There are perhaps a couple of dozen species living in and around Washington, D.C.

In the last several decades, there has been a dramatic decline in the number of fireflies worldwide. James Lloyd, a retired professor of entomology at the University of Florida at Gainesville, says, "I've probably spent well over 2,000 nights in the field. I can't find a lot of species locally that I found 35 or 40 years ago." No one knows the cause, but possible culprits include loss of habitat (particularly wetlands), overuse of pesticides, overcollection for research and medicine, and light pollution.

The vast majority of flashing fireflies on summer evenings are males advertising for a mate. However, both males and females use their flashes in many other situations as well. For example, they may flicker when trapped in spider webs, or when landing or taking off. Females of some species mimic the flashes of other species, then eat males that respond.

Fireflies have evolved specific adaptations to send and receive these lighted communications in the dark. Some species' light is yellow, while other species' light is green. For the most part, yellow species come out earlier at night than green species. Fireflies' vision has evolved in concert with their flashes, perhaps putting them at

Craig Mayhew and Robert Simmon/NASA GSFC

A composite of satellite images from 2000 shows artificial light usage around the world.

risk for behavioral changes as they respond to artificial lights in particular spectral ranges.

While there have been few studies that quantify the effect of artificial nighttime light on fireflies, a number of studies have shown ways in which the behavior of fireflies is finely tuned to light levels. On clear days, *Photinus pyralis* males come out at twilight and begin signaling for mates, but on cloudy days, or in shady areas, they start signaling earlier. Another species, *Photinus collustrans*, adjusts the height of its flight depending on light levels. Soon after sunset, it flies near the ground; as darkness deepens, it flies higher. Like many insects, fireflies are also attracted and "trapped" by streetlights and porch lights.

"How disturbing is the light we put into the habitat, either directly from point sources or indirectly bouncing off the clouds?" Lloyd asks. "I think it's devastating."

How disturbing is the light we put into the habitat, either directly from point sources or indirectly bouncing off the clouds?

Turning Down the Lights

The International Dark-Sky Association has long worked to curb light pollution in the interest of star-gazing and astronomy. Now, others are beginning to spread the word that light pollution hurts animals. Catherine Rich and Travis Longcore of The Urban Wildlands Group in Los Angeles, California, recently edited a book called *Ecological Consequences of Artificial Night Lighting* and are currently putting together best lighting management practices for national parks.

Their recommendations to homeowners for putting a lid on light pollution? "Use the minimum necessary for security, and have it be fully shielded and pointing downward to the place where light is necessary," Rich says. "Have a motion detector—then you're only lighting when there's something going by that needs to be illuminated. Don't uplight your trees or house." Longcore adds, "Stay away from lights that have ultraviolet or [are at the] blue end of the spectrum. Stay away from metal halide and mercury vapor. Use yellow lights [that won't attract bugs]."

Many communities, particularly in desert areas, have adopted light ordinances. A typical ordinance might include requirements that outdoor lighting be fully shielded (so that light rays go down, not up); that lights at playing fields be properly shielded and be turned off at 10:30 or 11 p.m.; that billboards and other signs be lit from the top, not bottom; that businesses turn off parking-lot lights 30 minutes after closing; and that searchlights and laser lights not be used for advertising.

"One of the big challenges is that there is no silver bullet," Longcore says. White strobe lights on towers might be best for migrating birds, but are more annoying to humans living nearby. Yellow lights might not bother nesting sea turtles, but they disorient hatchlings. Lights that point down don't contribute to sky glow, but they might adversely affect tadpoles in a ditch below them.

"The best thing we can do with any natural habitat," he says, "is keep it dark." Z

—Mary-Russell Roberson is a contributing editor to ZooGoer. *She wrote about animal song in the May/June issue.*

Simon King/naturepl.com

A meerkat group stands at alert in the Kalahari Desert. Meerkats are highly social mammals that cooperatively defend territory, breed, and raise young.

WARRIORS

of the Kalahari

BY MILES ROBERTS

"We could be in for an interesting morning," Rob said over the radio. "The Balrog group is starting to forage and they're headed straight toward you."

"We're on the move but our guys haven't seen your guys yet," I replied. "Will keep you posted."

I was with the Gattaca group, composed of more than 30 meerkats. Gattaca wasn't the largest in the area but certainly larger than the Balrog gang of about 20 animals that Rob was monitoring. The previous night the two groups retired only about a couple of hundred yards apart, apparently without noticing each other. Rank sourgrass may have obscured them as they settled down in the fading light. Usually, groups don't tolerate being so close, and when they are a showdown erupts, ending with one group giving way, sometimes after losing a member or two—even pups—in battle.

So far, Gattaca showed no evidence of having seen Balrog. Pups were playing around the den and the dominant male and female were slowly mobilizing after warming up. No one was foraging yet, and no sentinels had taken position on a shrub or snag to scan for predators, as they would shortly. After spending two and a half weeks with eight meerkat groups, I was beginning to get a sense of their daily routine. Today seemed pretty typical, but Balrog's proximity promised to change the schedule.

I was working as a volunteer on Tim Clutton-Brock's meerkat project in the southern Kalahari; Rob is a student on Clutton-Brock's team. A professor of ecology at the University of Cambridge in England, Clutton-Brock and his team, along with collaborators that include Steven Monfort, associate director for conservation and science at the Smithsonian's National Zoo, have been studying meerkats since 1993, trying to sort out their complex social lives.

As the group moved out, a few meerkats climbed up on fallen logs and shrubs to scan the environment to act as sentinels.

Social Desert Dwellers

Meerkats (*Suricata suricatta*) are small, social mongooses that breed cooperatively and live in groups of six to 40 or more individuals. They spend the night huddled together underground in sleeping burrows dug by springhares, aardvarks, and other burrowing denizens of this harsh desert environment.

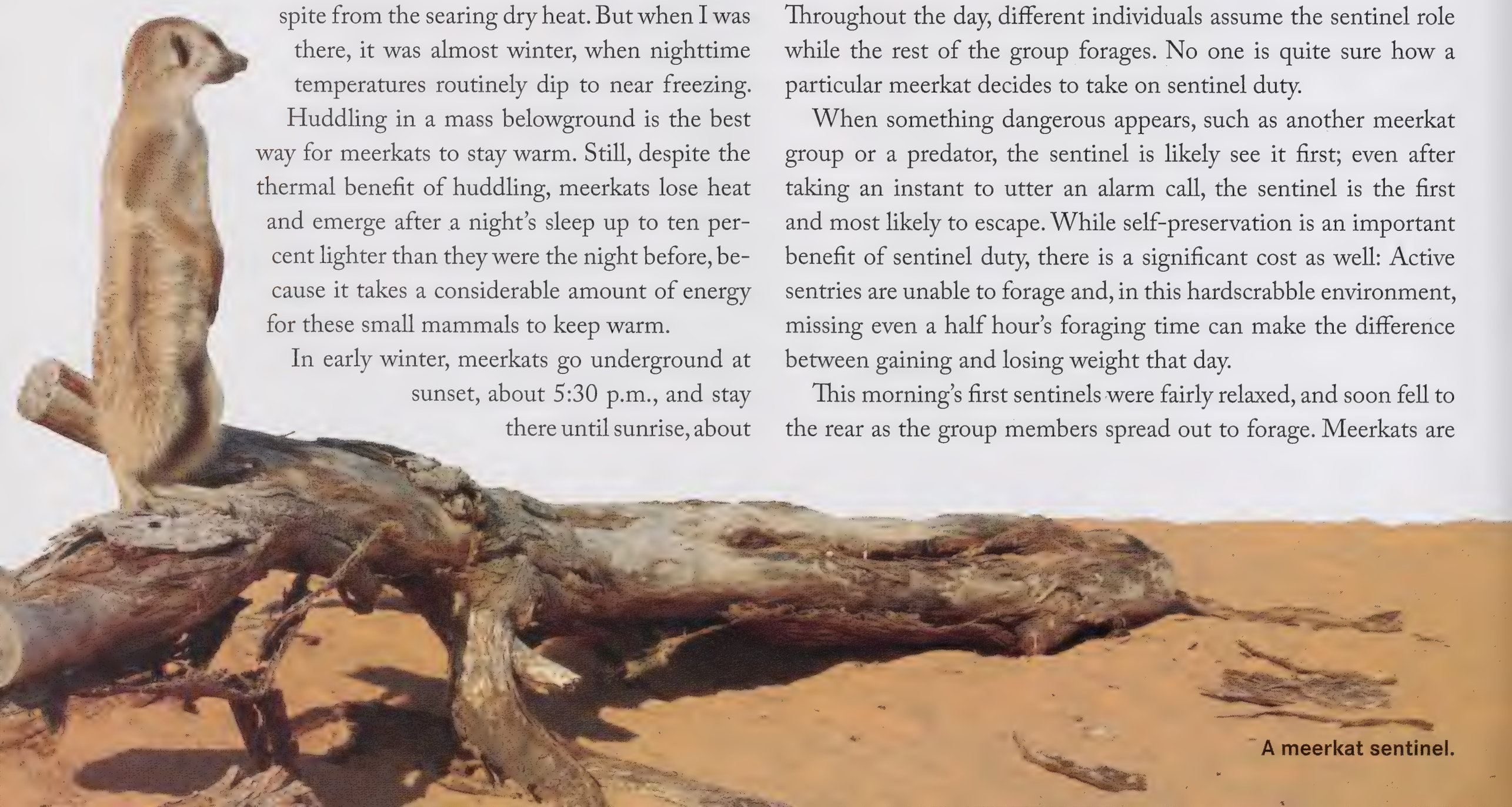
In the Kalahari, where summer daytime temperatures can reach 115°F, burrows offer meerkats security as well as respite from the searing dry heat. But when I was there, it was almost winter, when nighttime temperatures routinely dip to near freezing. Huddling in a mass belowground is the best way for meerkats to stay warm. Still, despite the thermal benefit of huddling, meerkats lose heat and emerge after a night's sleep up to ten percent lighter than they were the night before, because it takes a considerable amount of energy for these small mammals to keep warm.

In early winter, meerkats go underground at sunset, about 5:30 p.m., and stay there until sunrise, about 7:15 a.m. In the morning, meerkats slowly emerge one by one and it may take 20 minutes or more for everyone to surface. Then, the long process of completely waking up begins. The animals, some alone and some in small groups, stand on their hind legs and face the sun to soak up solar energy until their droopy heads finally snap to attention. (Like some other small, insectivorous mammals I have studied, such as big hairy armadillos (*Chaetophractus villosus*), southern tamanduas (*Tamandua tetradactyla*), and dwarf mongooses (*Helogale parvula*), meerkats may reduce their core body temperatures and metabolic rates at night to save as much energy as possible. If so, this would explain their drowsy emergence and prolonged wake-up time.) After a 30-or-so minute warm-up, the meerkats start to interact, groom, and engage in burrow maintenance. Gradually, the orbit of activities shifts from the area immediately outside burrow entrances to the surrounding vegetation. Soon a few individuals start to forage nearby, but it isn't until the dominant male and female head out, often signaling the rest with a "follow-me" call, that the group begins its daily foraging sojourn in earnest. It may travel as far as a couple of miles away to a new sleeping den by day's end.

This morning, after a clear, freezing-cold night, Gattaca is particularly slow getting up, and if these meerkats were aware Balrog was nearby they weren't letting on. As the group moved out, a few meerkats climbed up on fallen logs and shrubs to scan the environment to act as sentinels. This behavior is characteristic of meerkats. Throughout the day, different individuals assume the sentinel role while the rest of the group forages. No one is quite sure how a particular meerkat decides to take on sentinel duty.

When something dangerous appears, such as another meerkat group or a predator, the sentinel is likely see it first; even after taking an instant to utter an alarm call, the sentinel is the first and most likely to escape. While self-preservation is an important benefit of sentinel duty, there is a significant cost as well: Active sentries are unable to forage and, in this hardscrabble environment, missing even a half hour's foraging time can make the difference between gaining and losing weight that day.

This morning's first sentinels were fairly relaxed, and soon fell to the rear as the group members spread out to forage. Meerkats are



A meerkat sentinel.

All photos by Miles Roberts

After the day's foraging is done, meerkats gather near their burrows to capture the last rays of the sun and reestablish social ties.

primarily insectivorous and scratch incessantly at the ground to search for subterranean insects, spiders, scorpions, millipedes, larvae, pupae, and even the occasional lizard. Foraging is hard work and the meerkats frantically excavate the crusty soil surface where they are likely to find prey, usually near the base of a grass tussock or shrub. Every third or fourth scrabble becomes a major excavation—a meerkat can dig out a quantity of red Kalahari sand equivalent to its own body weight in 30 seconds or less. These scrabbles appear random and speculative, but are successful surprisingly often. Meerkats have excellent senses of hearing and smell, so excavations may be prompted by the sound or scent of a prospective meal.

Meerkats have excellent senses of hearing and smell, so excavations may be prompted by the sound or scent of a prospective meal.

I often spent entire mornings following individual meerkats to see what they caught. But most of the prey the meerkats consumed with an audible crunching chew (usually the only way to tell that something had been caught) was too small for us to see, let alone identify. "Small something" was the most frequently recorded item in our notes. A meerkat's day's work consists mostly of foraging for dozens and dozens of these small somethings with, if it's lucky, an occasional medium or large something.

Centipede prey.

Although it is important for meerkats to find enough food for themselves, they sometimes donate food to others, almost always to young pups that are just learning to forage. Litters, which on average contain three to five pups, typically emerge from their burrows for the first time when they are about three weeks old, and accompany the foraging group for the first time when they are about five weeks old. While they can keep up with the group, pups are still developing their digging and foraging motor skills and are unable to feed themselves effectively. To get something to eat, they stand near an adult and constantly emit a begging call that seems to become harsher and more annoying as the day wears on. Occasionally, an adult captures a prey item, usually a relatively large one such as a beetle larva or scorpion, then drops it in front of a begging pup that greedily and noisily accepts it. Why an adult donates a particular food item at a particular time is unclear, but all of us working on the project agreed that if we were meerkats we would donate whatever food it took to make the horrible begging sound stop!

Some pups are more successful at garnering feedings than others, and we noted that adult "helpers" in some groups are more generous pup feeders than in others. Over the course of the study, Clutton-Brock and his collaborators have learned that female helpers tend to feed pups more than males do, and they preferentially feed female pups. Regardless of sex, adults are more likely to feed pups larger items than smaller ones, and to feed the nearest pup even if it means running ten yards or more to find one. This helping behavior affects the pup directly but also benefits the group as a whole. Clutton-Brock has found that groups with higher ratios of helpers to pups have faster-growing pups that are more likely to survive and become future helpers themselves.

Pups are highly vulnerable to predators, and when they first embark on foraging forays, there is palpable tension in the group. Frequent stops are made at bolt-holes—entrances to burrows the animals can dive into for safety—where the pups play while edgy adults stand at high alert looking nervously all around. While they are traveling between bolt-holes, the least suspicion results in an alarm call and a mass scurrying for the nearest bolt-hole, with most of the meerkats heading for the same one or two holes even when the group is spread out. In experimental field studies, Marta Manser, a collaborator of Clutton-Brock's, found that even though a meerkat group may have more than 1,000 bolt-holes in its territory, individuals seem to have very detailed knowledge of the location of and distance between bolt-holes, even if they haven't recently visited them. It is likely that pups learn the locations of the bolt-holes on their early foraging expeditions.

Meerkats have many predators, both aerial and terrestrial. Among the terrestrial are jackals (*Canis mesomelas*), bat-eared foxes (*Otocyon megalotis*), wildcats (*Felis silvestris*), and caracals (*Caracal caracal*); all but the jackals are nocturnal, so they are not serious threats when meerkats are huddled in their burrows at night. Among the aerial predators, a variety of raptors are a threat, especially the massive martial eagle (*Polemaetus bellicosus*)—the meerkats' worst nightmare.

All predators elicit alarm calls from sentinels, but the alarm call alerting the group to a terrestrial predator is different from the one for an aerial predator. The magnitude of the predator threat is also encoded in the intensity and structure of the alarm call. Thus, the alarm-call system appears to convey the type and urgency of a threat, so as soon as the alarm is heard, the listeners know its immediacy and whether the threat is by ground or by air. A glance at the caller reveals the direction from which the threat is coming because it has its eyes glued to the source of its concern.

A potentially dangerous but not immediately threatening animal, such as a sluggish puff adder (*Bitis arietans*), elicits another response called "mobbing." In mobbing, most or all group members cluster around the threat with tails held high and heads bobbing to harass it into retreating. I can testify to its effectiveness. One evening, I was lying next to the burrow of a group called Moomins, eyeball to eyeball with the animals, when my broad-brimmed straw hat fell from my head to the ground. Apparently, as long as the hat was on my head it was acceptable to the meerkats. But as soon as it became a separate entity, it was like a puff adder. Within seconds, all 30 Moomins were mobbing my hat and my face next to it. From my ground-level perspective, I was suddenly among what seemed like a huge, multitailed, pulsating, feinting, swerving, threatening alien organism. Unnerved, I retreated like any puff adder would.

Leaders of the Pack

Back with Gattaca, I saw the sentinels stiffen at their posts and it was clear they had seen something in Balrog's direction. "Looks like you've been spotted, Rob," I said into the radio. "Get ready!"

Meerkats in Exile

Dominant female meerkats may kill any young her subordinates dare to produce, but subordinate females are no less ruthless. They too may kill the dominant female's pups—but they aren't often given the chance. Instead, the usually friendly relationships between a dominant female and some subordinates begin to sour as a dominant enters the last weeks of her 70-day pregnancy. The dominant, which is usually the heaviest female in the group, becomes a virago. She hits, bites, charges, and chases some subordinate females until they leave the group to escape the constant harassment.

Miles Roberts

The exiles stay in the group's territory but forage and sleep alone or with other exiles. Whenever the dominant female runs into an exile, she chases and attacks her some more. Then, about three days after the dominant gives birth, many of the exiled females return to their group; once her young are a few days old, the subordinates will not kill them. Peace reigns again among the females, until the dominant is well into her next pregnancy.

The dominant is selective about which subordinates she forces into exile. Females younger than about nine months, which rarely conceive, are left alone. In contrast, older females, especially those that are pregnant, as well as females more distantly related to the dominant, are exiled on more than 40 percent of the possible occasions, according to a recent study published in the ***Proceedings of the National Academy of Sciences***. The findings are the result of a long-term collaboration between the Smithsonian National Zoo's Steven Monfort,

But nothing was likely to happen until the still-oblivious dominant male and female led the way.

The dominant couple controls much that happens in meerkat society; the dominant female, in particular, wields great power. Dominant females produce more than 80 percent of the pups that survive their first month. Subordinate females may breed from time to time, but the dominant female usually kills their pups to maintain reproductive supremacy. Older subordinate females may also be temporarily exiled from the group during the latter part of the dominant female's pregnancy (see sidebar). It is during these exiles that subordinate females are most likely to mate with males from other groups that are prospecting for breeding opportunities (although conception rates are low), because they, too, are reproductively suppressed by the dominant male in their own groups. Sometimes alone and sometimes in small coalitions, males search for females to mate, insinuate themselves into another group (where, unlike females, they may be accepted), or even form a group of their own with footloose females in exile.

Females rarely disperse from their natal groups; instead they stay and wait for the chance to become dominant if and when something happens to the reigning matriarch. An older subordinate female in exile sometimes forms a new group with a prospecting male, but a female is never accepted into an established group. New group formation is hazardous because small groups are much less likely to survive than large ones during a prolonged drought or other difficult conditions.

Thus, individual meerkats are confronted with a rather harsh life decision: stay with the group as a nonreproductive helper and accept the low probability of becoming a reproductive dominant, or leave the group, breed almost immediately, and try to form a new group, but with much lower odds for success. Before taking one or the other of these courses, subordinate meerkats undergo

Miles Roberts

Like most pups, this youngster is probably the offspring of the dominant female.

a kind of apprenticeship during which they learn how to forage, locate bolt-holes, take turns being sentinel, provision pups, and babysit at the den. Of all these assignments, babysitting seems to be the most demanding.

When her pups are born, the dominant female almost immediately leaves them in the care of babysitters that spend the entire day at the burrow keeping guard and nursing them. Some of the wet-nurses are females whose own pups have been killed by the matriach, but there are also cases of spontaneous lactation in nonreproductive subordinates. Other than nursing, the dominant female gives little care to her pups, and spends most of her time foraging. This gives the dominant female the energy to breed more frequently and produce larger litters. For their work, the babysitters

the University of Cambridge's Tim Clutton-Brock, and their colleagues.

It is clearly advantageous for a dominant female to exile infanticidal subordinates. But this study revealed an additional twist. The stress of being exiled wreaks havoc with the subordinates' own chances of reproducing, explaining, at least in part, how the dominant maintains her breeding monopoly.

The chronic stress of an exile, measured by elevated levels of stress hormones produced by her adrenal glands, makes an exiled female more likely to abort if she is already pregnant, and much less likely to conceive if she mates during exile. In fact, only one female in the study conceived during her exile.

A dominant female benefits from suppressing reproduction in subordinates by reducing or eliminating competition for the child care provided by subordinate helpers. The more helpers per pup, the faster the pup grows and the greater its odds of surviving. Up to a point, dominants are more likely to exile subordinates as group size increases and competition intensifies. In very large groups, however, the chances of a subordinate being exiled decreases, suggesting that it's just too expensive energetically for the pregnant dominant to force out many subordinates at the same time. Similarly, dominant females with low body weights are less likely to use energy to exile subordinates than heavier females are.

Dominant individuals that suppress the reproduction of subordinates and use them as helpers exist in a variety of vertebrates that breed cooperatively, including African wild dogs (***Lycaon pictus***), Florida scrub jays (***Aphelocoma coerulescens***), and ring-tailed lemurs (***Lemur catta***). But in these and several other cooperatively breeding species, scientists have ruled out chronic stress as the cause of suppression. The results of this study show, however, that stress may play a role in other species not yet tested—or that meerkats are unique.

—Susan Lumpkin

Miles Roberts

Resting at the end of the day.

get little directly in return. A day of babysitting is a day without foraging, and babysitters may lose substantial amounts of weight. As is the case for sentinels, we don't know how a meerkat decides to babysit or not: There is no obvious rotation or schedule. All subordinate adults and yearlings guard the den and take turns babysitting, but older males spend less time doing so, in part because they go off prospecting and aren't around. There also appear to be "generous" and "lazy" helpers in meerkat groups, but lazy helpers don't seem to suffer any negative consequences and generous ones don't seem to be rewarded.

Gattaca Versus Balrog

Helpers also contribute in times of crisis, like the one I saw brewing in the Gattaca group. Some of Gattaca's frontline foragers were on high alert, clearly having detected the Balrogs nearby. Gattaca had been relatively spread out, but now all of its members were headed toward Balrog. The front line was in full pursuit while the rest, including the pups, ran to catch up, heads bobbing up and down as first one, and then another meerkat stopped for a second, assumed an elevated vigilant position to get a better view of the prospective field of battle, and scurried back to the group. I had been warned that these intergroup interactions, or "iggies" in the vernacular of the seasoned meerkat watcher, could erupt suddenly and be very chaotic. Iggies are all about territory, and they usually result in the establishment of new territorial boundaries, with the smaller group typically losing ground to the larger one.

Meerkats vigorously defend their territories because they contain the precious resources needed for survival; food and shelter are of utmost importance. In the Kalahari's very harsh, semi-arid climate, food resources fluctuate considerably between wet and dry seasons and between years. At the study site, mortality due to food competition within the large groups may be higher than mortality due to predation. Clutton-Brock's studies have also shown that during one year of extremely low rainfall, all meerkat groups consisting of nine or fewer individuals went extinct, probably due to lack of food. So acquiring and maintaining a quality territory, through iggies if necessary, is an important part of meerkats' survival strategy.

For the most part, iggies are bloodless power plays, but occasionally groups engage fiercely and meerkats are injured or killed. If one group invades another's burrow when only pups and babysitters are at home, the gruesome fact of meerkat life is that the pups are almost always killed.

Gattaca was united and moving purposefully toward the smaller Balrog group. It was my last day in the Kalahari and, while iggies are exciting departures from the norm, I had gotten to know some of the animals well enough to not want to see any of them get hurt. This is unscientific, but anyone who has spent time with meerkats knows what I'm talking about: Their individual personalities had emerged. Meerkat sentinels had climbed on me to find the highest available perch. Tiny pups had leaned against my leg while warming up in the morning sun. I had spent part of an afternoon foraging like a meerkat, searching for insects, grubs, pupae—anything—and failed so miserably that I was humbled by the meerkats' abilities and work ethic. I had witnessed their clan skirmishes and family squabbles; been scent marked and mobbed; and had chilled out with my groups at the end of long workdays, watching the sun go down. The prospect of spending my last day discovering the meerkats' dark side did not appeal to me.

Fearing the worst, I followed the group with trepidation. Then Rob called by radio. "Looks like Balrog is opting out, heading off away from Gattaca," he reported. Fortunately for me, discretion was the better part of valor for Balrog as, outnumbered, the group scooted away. Gattaca assembled around a large pile of brush that served as an excellent vantage point for several sentinels, a safe haven for the rest, and a playground for the pups. The group seemed content to declare victory and take a midday break a few hours early.

I returned to camp and hadn't planned to go out again. But meerkats can cast a spell on you. A few hours later, I heard their siren call and decided to try to find Gattaca one last time. I started my search where I left the group in the morning but the meerkats were nowhere to be found. A little disappointed, I headed toward camp along a game trail. About halfway back, I heard a rustle and looked up to see three Gattaca pups running through the grass and down the trail toward me, an adult following close behind. I felt elated—as if my family were greeting me as I returned home at the end of the day. Of course they weren't, and the meerkats ran past me, giving me one of those "oh, you with the hat again" looks. Everything was back to normal. It was a good time to leave. Z

—Miles Roberts is a scientist in the Zoo's Conservation Education and Sustainability Center.

What's Size Got to Do With It?

Amazing Numbers in Biology
Rainer Flindt. 2006. Springer-Verlag, Berlin. 295 pp., softbound. $29.95.

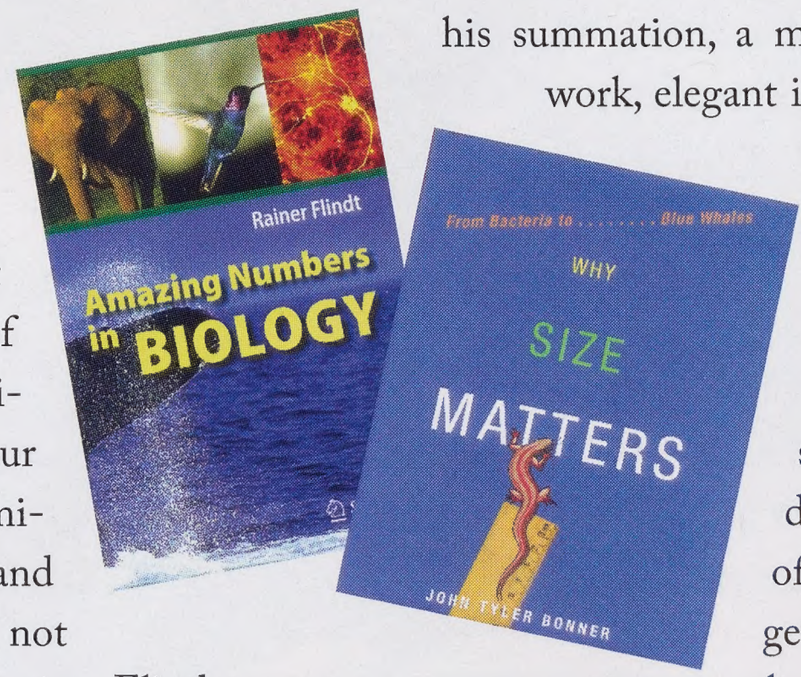
Why Size Matters: From Bacteria to Blue Whales
John Tyler Bonner. 2006. Princeton University Press, Princeton. 161 pp., hardbound. $16.95.

How big is it? How small is it? People are fascinated by the size of things. At the Zoo, the labels that identify animals invariably include their weight or length or both. And, in fact, knowing an animal's size tells us a lot.

You may not have heard of an animal called a bongo, but if I say one weighs between 500 and 900 pounds, you'll immediately know what it's *not* even if you have only passing familiarity with the animal kingdom. You can eliminate all invertebrates and all birds and amphibians. Adding that a bongo is about five feet tall omits reptiles and fish.

You can also easily eliminate almost all mammals, the vast majority of which—rodents, bats, and the like—are small. Of the big ones, only a few exceed 500 pounds, and others are too big—rhinos and elephants, for instance. Now you're down to just a few possibilities: Only some whales, carnivores, and artiodactyls (even-toed ungulates) are this size. You might need a few more clues to figure out that a bongo is an artiodactyl (specifically, an African bovid), but in a multiple-choice test, a random guess would give you a one-in-three chance of getting the correct answer.

Knowing something about animal sizes may help you pass a pop quiz or win at Jeopardy. This knowledge also clearly has some intrinsic interest for most of us, and it's easy to find the size—weight, length, height, diameter, et cetera—of almost any species, as well as lists of the biggest, smallest, or tallest of whatever group you're interested in. But if you are curious about how much an elephant's heart weighs (about 43 pounds) or how long a sperm whale's intestines are (945 feet), or the diameter of a lion's eyeball (1.4 inches), *Amazing Numbers in Biology* is the book for you. It should certainly be on the shelves of parents with school-age kids.



German biologist Rainer Flindt has assembled an amazing—the title doesn't exaggerate—array of what scientists call "biological values" in four categories: zoology, microbiology, botany, and human biology, and not only values related to size. Flindt covers a huge number of such disparate and intriguing things as "daily urine volume in humans at different ages," "auditory acuity of selected animals," and "lifespan of leaves and needles of selected evergreen plants." If you're like me, you'll open this volume to look up, say, the pH values in the mid-intestine of a bedbug, and before you know it you'll be 20 pages on, checking out the blood pressure of a shark.

Amazing Numbers is even more interesting because Flindt puts so many values in a comparative perspective. For example, an elephant's huge heart forms only about four percent of its body weight, while a weasel's, at just 1/50 of an ounce, is nearly 17 percent of its weight, and a hummingbird's, which is slightly larger than the weasel's, is 24 percent of its weight.

Weirdly fascinating as it is, *Amazing Numbers* is pretty much raw data. *Why Size Matters* puts it all in perspective. In this small volume that you can read in an hour or two, John Tyler Bonner explores a big question: How does the size of an organism affect virtually everything else about it, from its ecology and evolution to its locomotion, life span, and the relative size of its heart and eyeballs?

Professor emeritus of ecology and evolutionary biology at Princeton, Bonner has been thinking about size and its implications for more than 60 years. *Why Size Matters* is his summation, a masterful and engaging work, elegant in its simplicity despite its subject's complexity. Bonner frames the book around five ways in which size rules. Strength, shape, complexity or division of labor, rates of processes such as longevity and speed, and abundance of organisms all vary with size, and they determine just about everything else, including most of *Amazing Numbers'* biological values.

If the handful of graphs and equations scare you, Bonner relieves the stress with a running discussion of how Jonathan Swift got the traits of Gulliver's Lilliputians and Brobdingnagians right or wrong. His examples of how "size rules life" are drawn from zoology, business, architecture, and transportation. And he has a way with metaphor. Because human sperm are so small, he writes, their movement is like that of a person "trying to swim in thick molasses in which one is not allowed to move one's arms or legs faster than the hands of a clock."

Try these two wildly different books on for size—I think you'll find they make a good fit.

—*Susan Lumpkin*

by Shannon Lyons

Defending the Dingo

Introduced species can wreak havoc on native flora and fauna, but the dingo (*Canis lupus dingo*), a wild dog that was introduced to Australia between 3,500 and 4,000 years ago, could save the animals upon which it preys. Dingoes are the top predators of Australia; along with red foxes (*Vulpes vulpes*) and feral cats (*Felis catus*) introduced by European settlers in the 18th century, they were blamed for extinctions and population declines in native ground-dwelling marsupials. But a recent study published in the November *Proceedings of the Royal Society B* shows that in areas where dingoes are rare or absent, small-mammal populations suffer and foxes and cats flourish. The study's authors concluded that dingoes maintain small-mammal biodiversity by killing cats and foxes, thus keeping predator populations in check. Dingoes are considered vermin that prey on livestock, and protecting them could be difficult. They have been poisoned, shot, and fenced out of grazing areas for centuries and are nearly extirpated from about half of Australia.

What's in a Name?

Although the second syllable of the word "meerkat" suggests its namesake is feline, the meerkat is really a member of the mongoose family. The origins of "meerkat" are more confusing than an English speaker might assume at first glance. In Afrikaans, a language derived from African dialects and Dutch, "meerkat" refers to all mongoose species. It probably comes from the Dutch ***meercatte***, meaning "sea cat" or "lake cat," a term Dutch traders applied to monkeys that were shipped from overseas. Meerkats' scientific name, ***Suricata suricatta***, also comes from a Dutch word for monkey—***surikat***, meaning macaque. It's unclear how these monkey monikers came to be used for mongooses that live in arid habitats.

The capybara (***Hydrochoerus hydrochaeris***), which is native to South America, is the world's largest rodent. An adult's combined head and body length may be more than four feet, and it may weigh up to 150 pounds.

Fact or Fiction: Only Mammals Bear Live Young

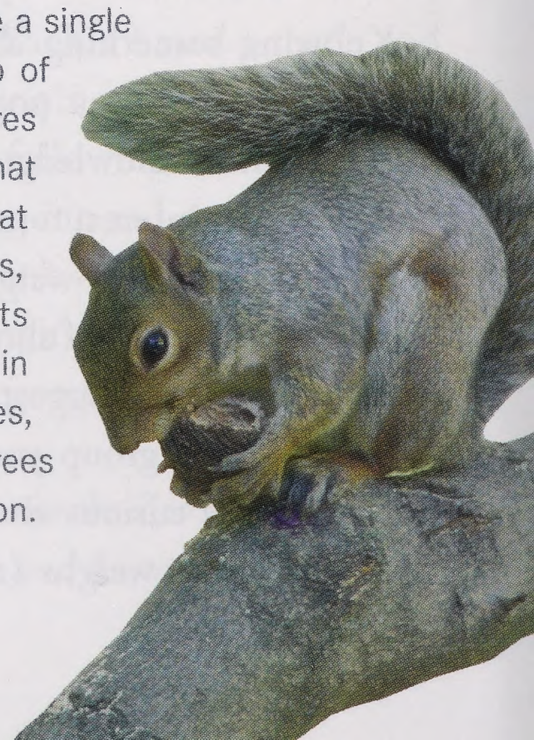
Mammals share three characteristics that are unique among animals, but bearing live young is not one of them. All nourish their young with milk produced by a female's mammary glands, have three inner-ear bones, and at some point in their development have hair (even manatees and other marine mammals have hair, and whiskers count!). While the vast majority, including placental mammals such as humans and marsupial mammals such as kangaroos, bear live young, monotreme mammals—the platypus (***Ornithorhynchus anatinus***) and two echidna species—lay eggs. Some sharks, reptiles, amphibians, and invertebrates also give birth to live offspring; in utero they are nourished by a placenta, the yolks of their eggs, or the flesh of their siblings.

In Season

The carryings-on of courting great horned owls (***Bubo virginianus***) interrupt quiet winter evenings in mid-Atlantic forests, swamps, and agricultural areas. Males hoot between dusk and sunrise until females answer their calls. When a pair meets, both birds cock their tails, bow, hold their drooping wings aloft, rub bills, preen one another, and engage in hooting duets. After this noisy display and their subsequent copulation, the female typically lays up to three eggs in an abandoned nest of a squirrel, hawk, or other bird, or in a crevice such as a cliff ledge.

How Do Animals Cache Food?

In the fall, eastern gray squirrels (***Sciurus carolinensis***) stash acorns in the ground, and black-capped chickadees (***Parus atricapillus***) conceal seeds in the crevices of tree bark; the food stores they hide help them survive winter or increase their chances of successful spring mating. Called "scatter hoarders," they spread their caches among dozens or even hundreds of hiding spots, so if other animals plunder a cache or two, their loss is minimal. Eastern chipmunks (***Tamias striatus***) are "larder hoarders" because they cache their food in one location. "Communal hoarders" such as taiga voles (***Microtus xanthognathus***) and American beavers (***Castor canadensis***) contribute to and share a single cache with a group of kin. And carnivores may cache kills that are too large to eat in one sitting. Bears, wolves, and cats conceal carcasses in caves, under leaves, or in the forks of trees for later consumption.



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